Update on climate trends in Hawai‘i

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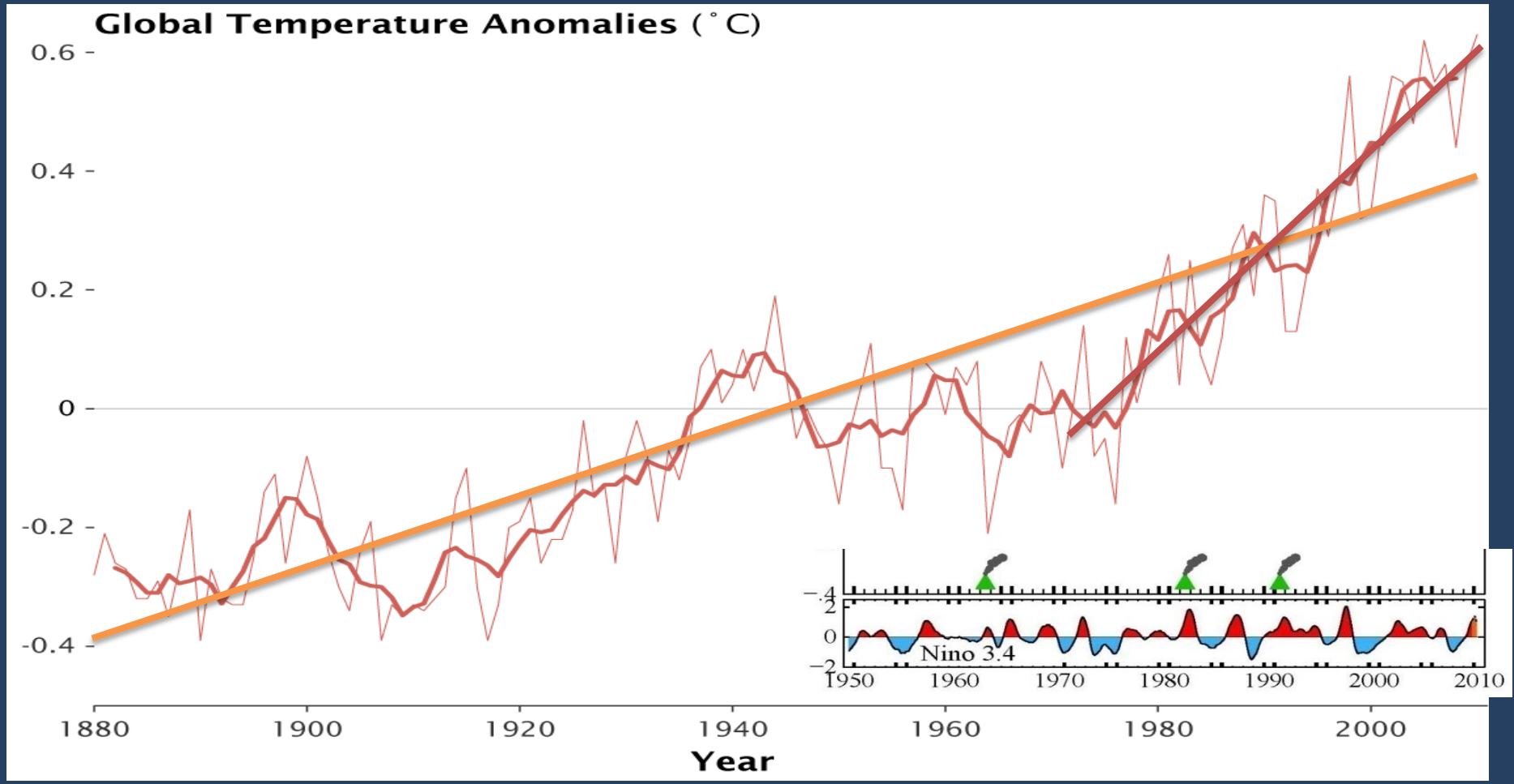
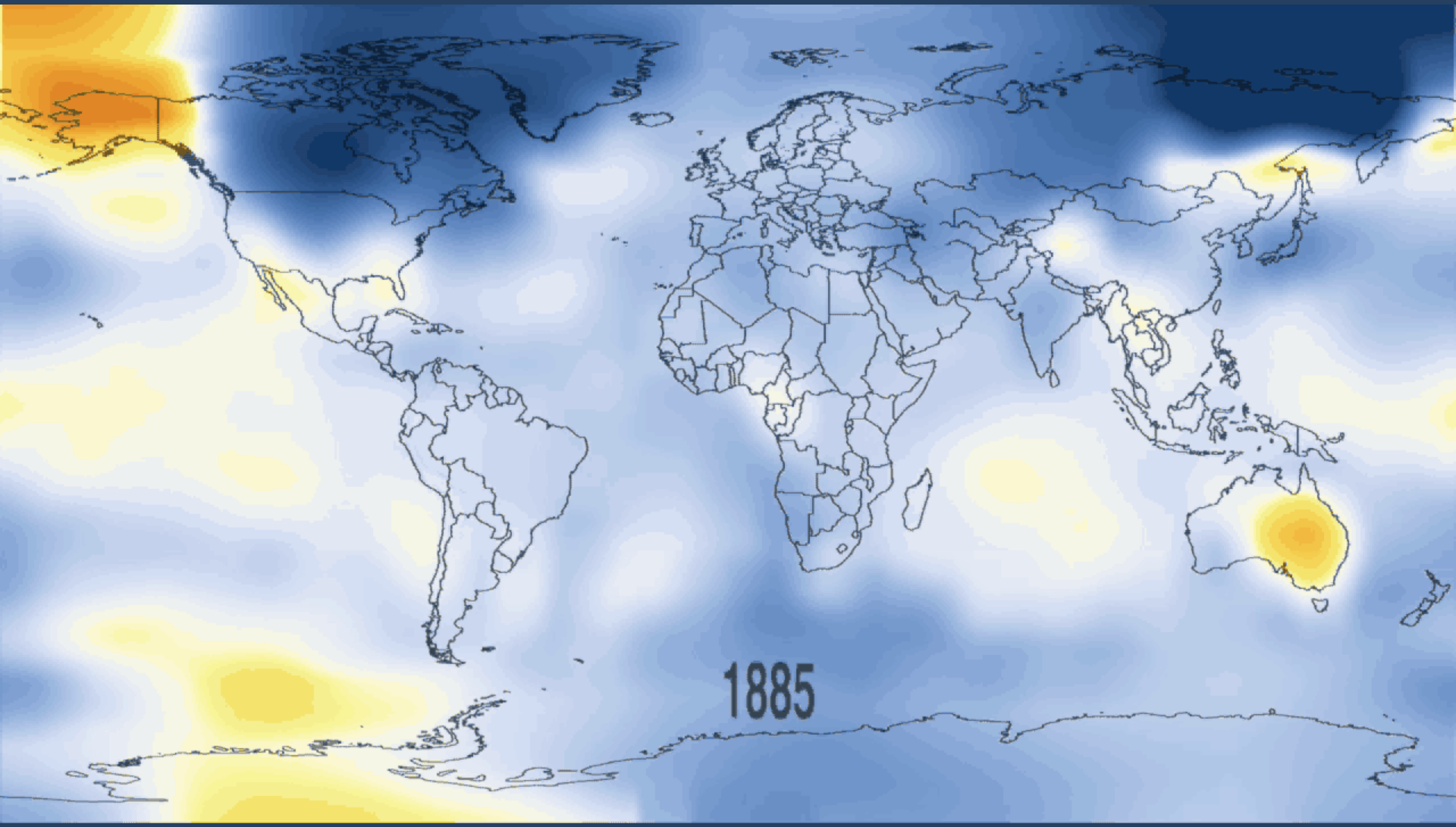
2010 – Tied as warmest year
1.34°F (0.8°C) total warming

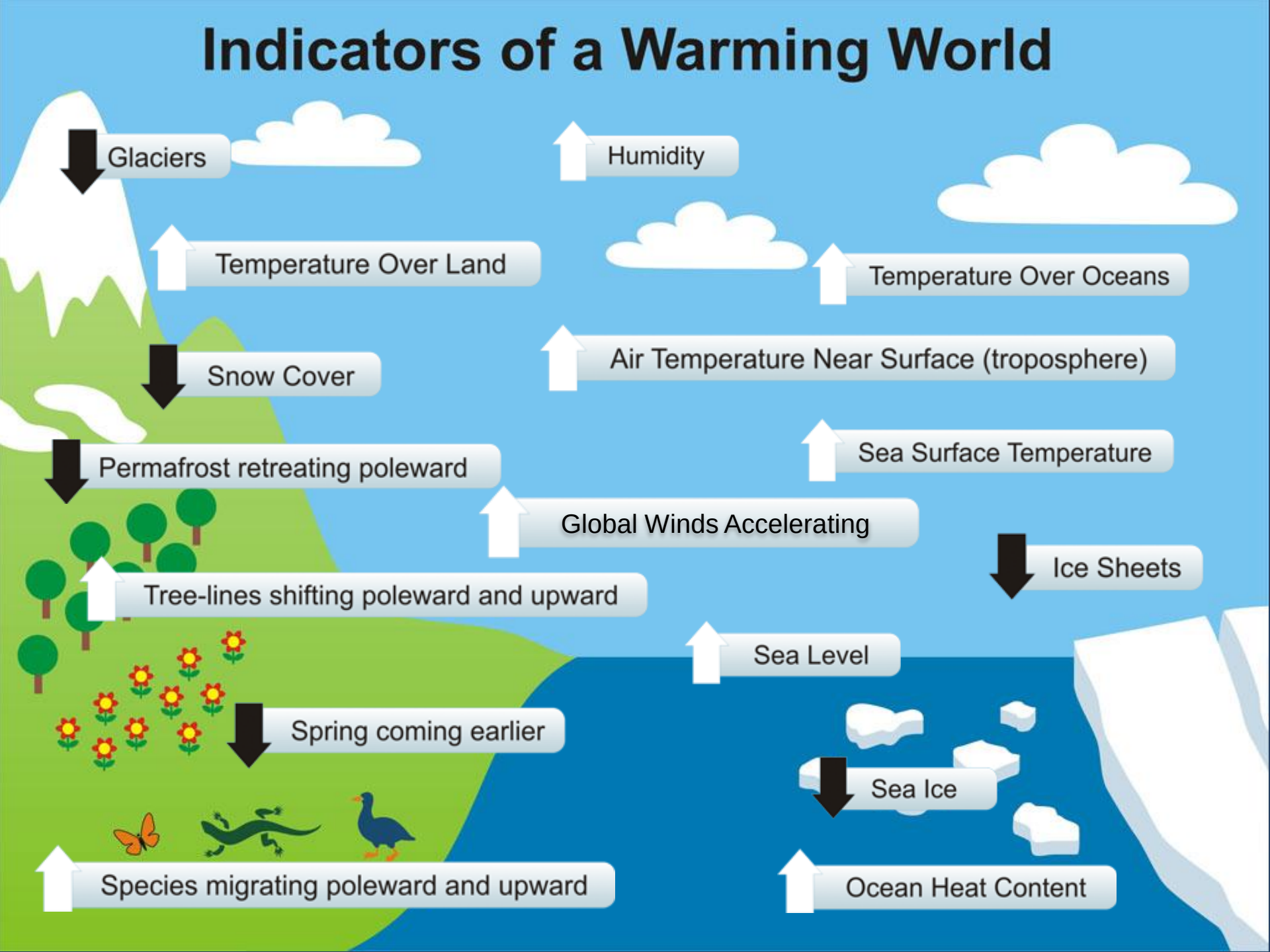


Global Surface Temperature Change, J. Hansen, R. Ruedy, M. Sato, K. Lo, 2010, NASA Goddard Institute for Space Studies, NY, NY



NASA Goddard Institute for Space Studies, NY, NY http://data.giss.nasa.gov/gistemp/

Indicators of a Warming World



U.S. National Academy of Science and Engineering

May 29, 2010

Some scientific conclusions have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of being found wrong is vanishingly small. Such conclusions are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities.

very likely = 90-99% probability

…strong evidence on climate change underscores the need for actions to reduce emissions and begin adapting to impacts.

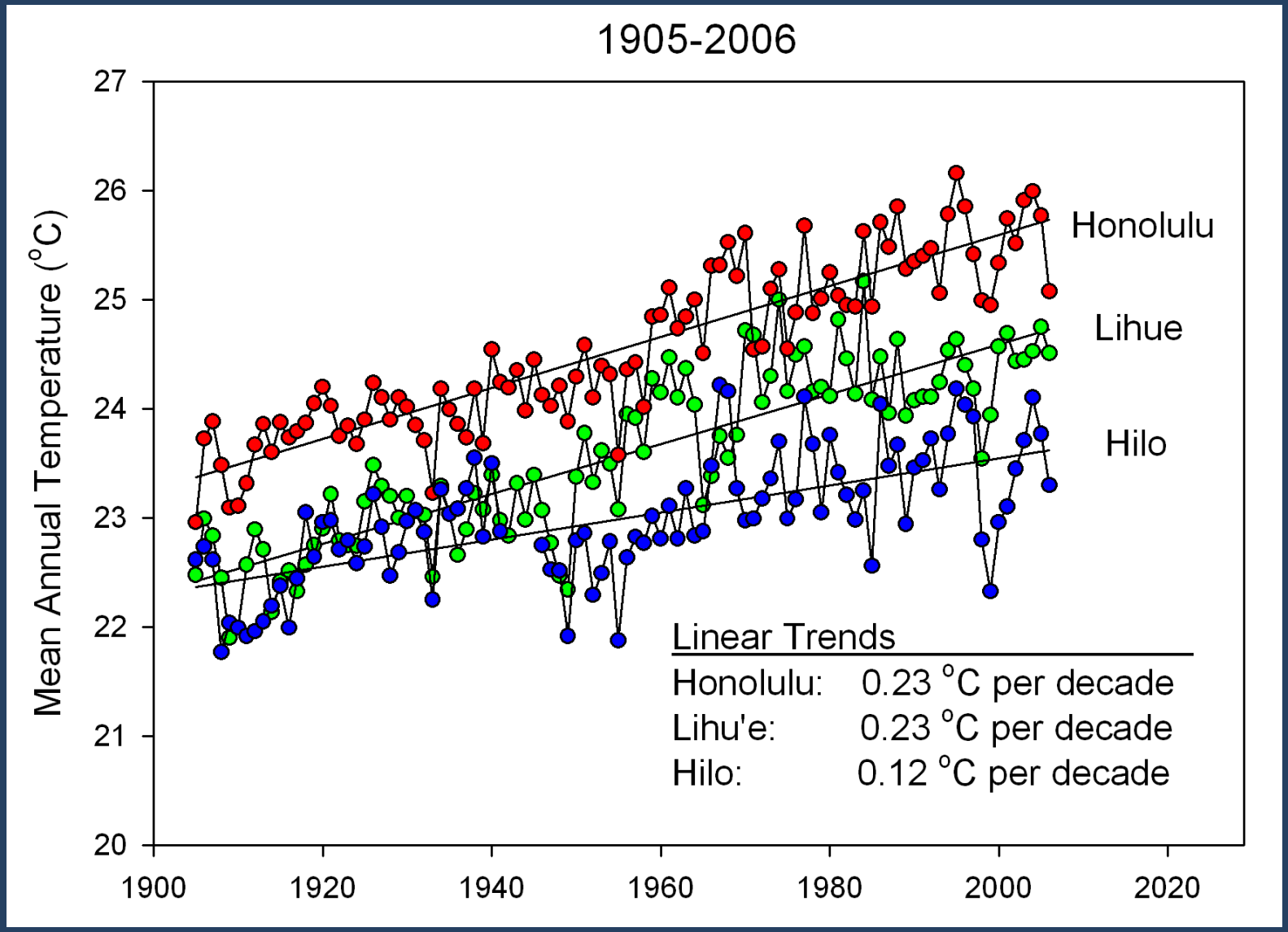
Advancing the Science of Climate Change – National Academies: http://americasclimatechoices.org/

Hawai′i Climate is Changing

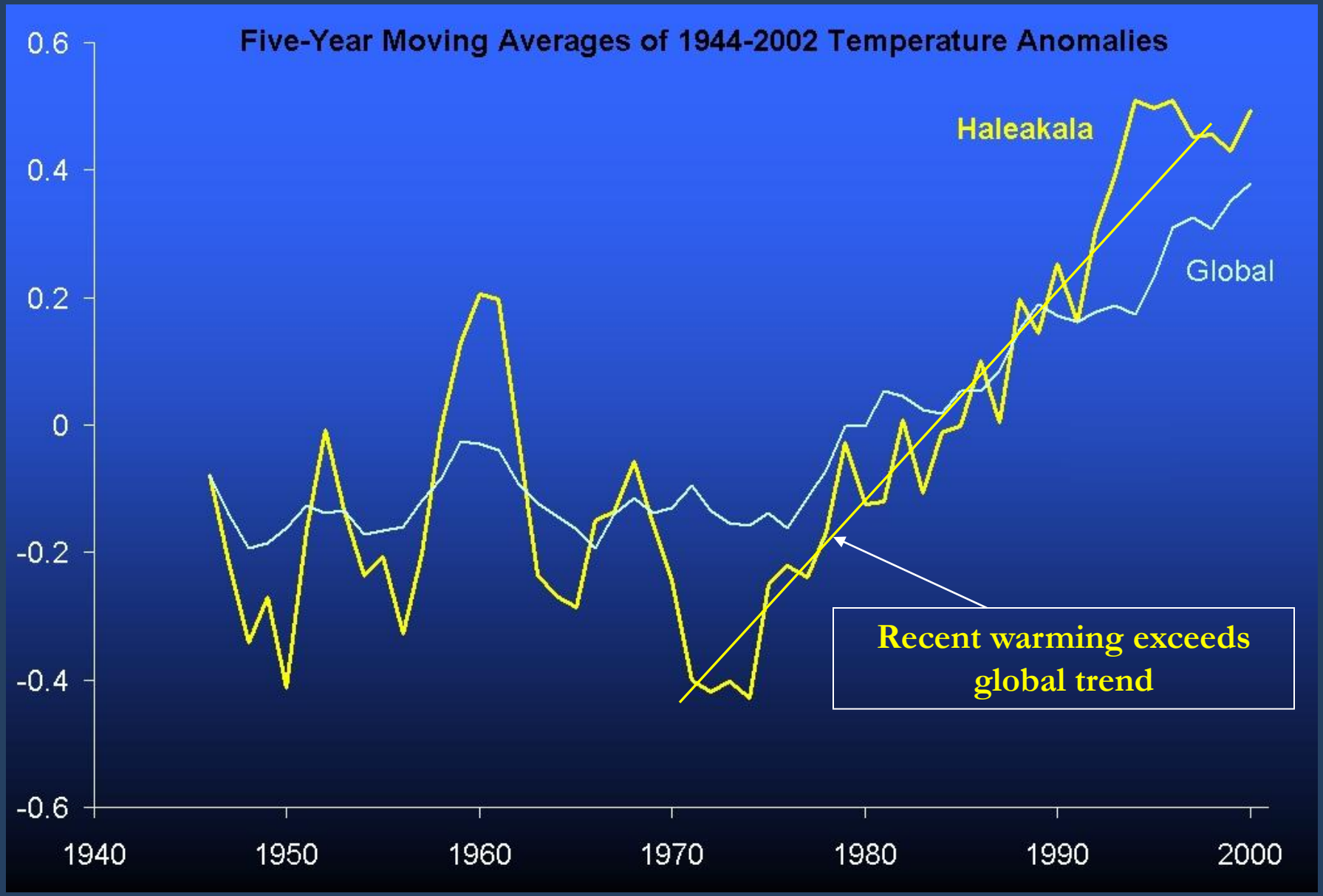
- Air temperature is increasing (0.3ºF/decade)
- Rainfall (-15%) and stream discharge have decreased
- Rainstorm intensity has increased (+12%)
- Sea surface temperature is rising (0.35ºF/decade)
- Ocean has grown more acidic
- Sea level is rising

Fletcher, C.H. (2010) Hawaii's Changing Climate (7p) University of Hawaii Sea Grant College Program, Center for Island Climate Adaptation and Policy, Honolulu

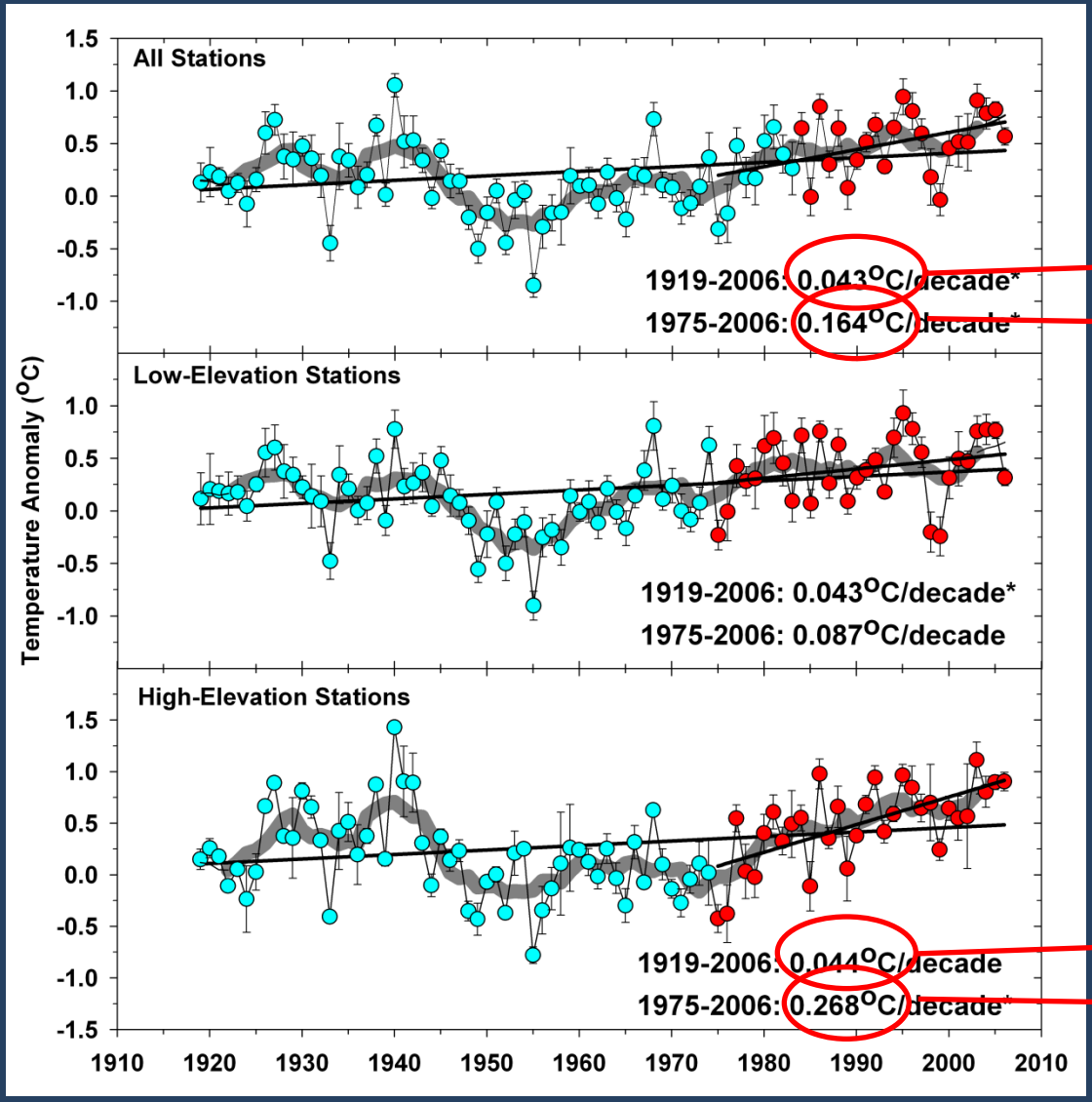
Temperature Trends



Temperature Trend at Haleakala



Hawai‘i Temperature Index



GLOBAL TRENDS:

1906-2005: **0.074°C** per decade

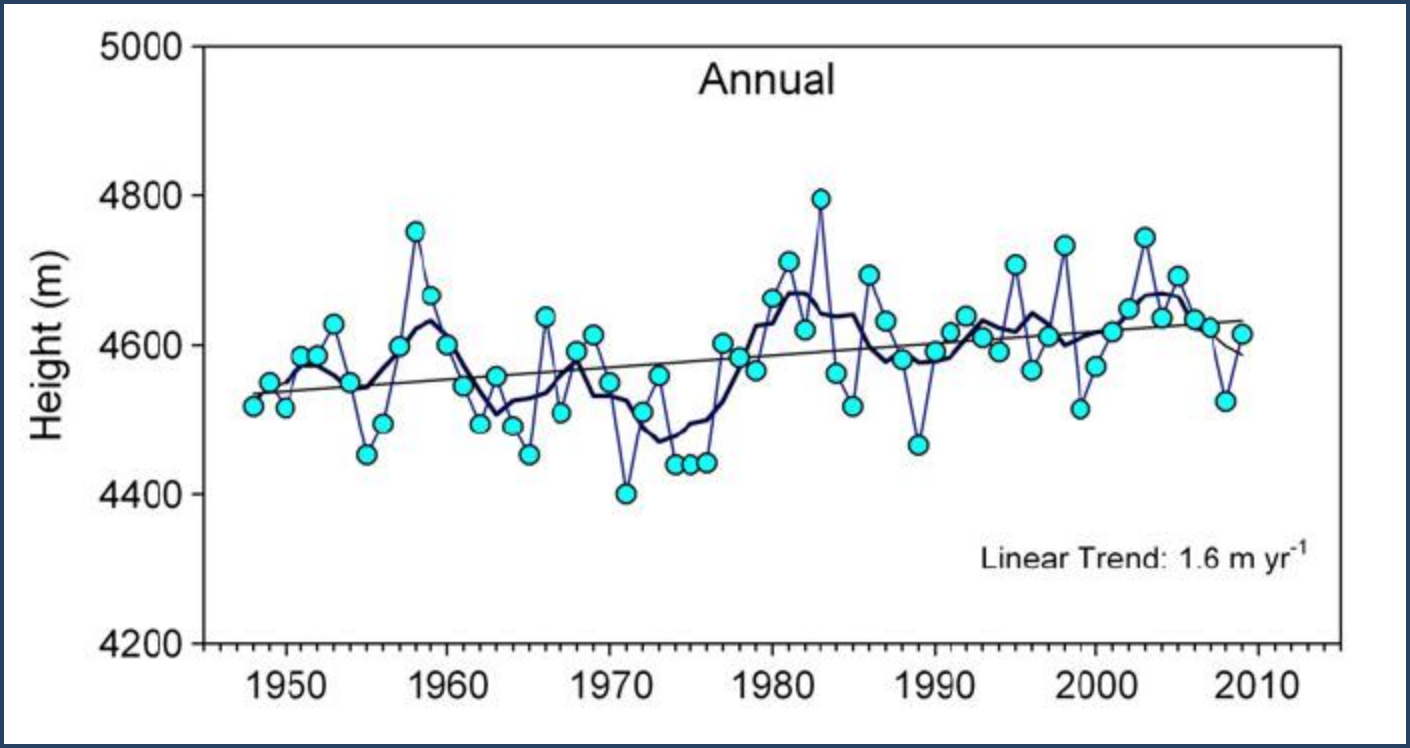
1976-2005: **0.177°C** per decade

Source: AR4, IPCC (2007)

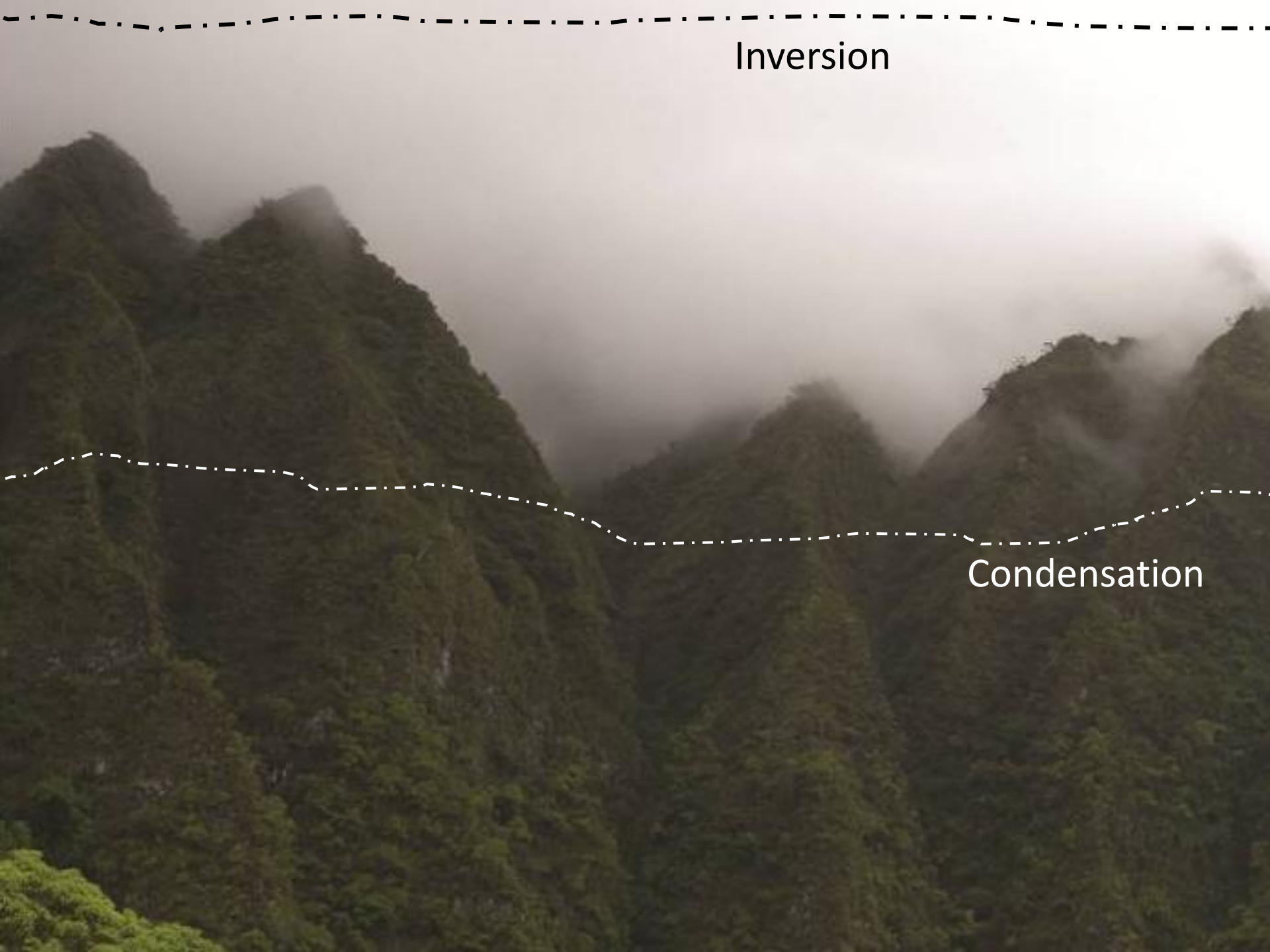
T. W. Giambelluca, H. F. Diaz, and M. S. A. Luke, 2008 “Secular Temperature Changes in Hawai‘i” *Geophysical Research Letters*, 35:L12702.

Trend in freezing level

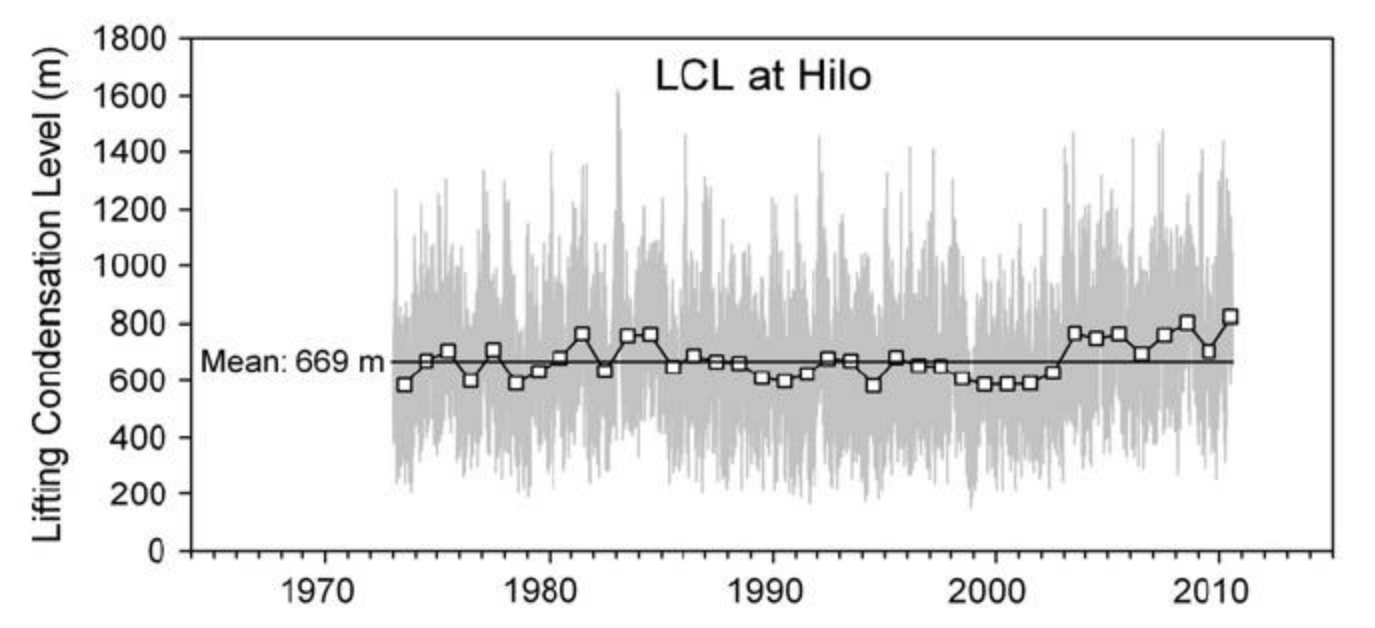
illustrates warming of the lower atmosphere and upward shift of temperature surfaces for the past several decades



Henry F. Diaz, Thomas W. Giambelluca, Jon K. Eischeid, 2011, Changes in the vertical profiles of mean temperature and humidity in the Hawaiian Islands, Global and Planetary Change, doi:10.1016/j.gloplacha.2011.02.007

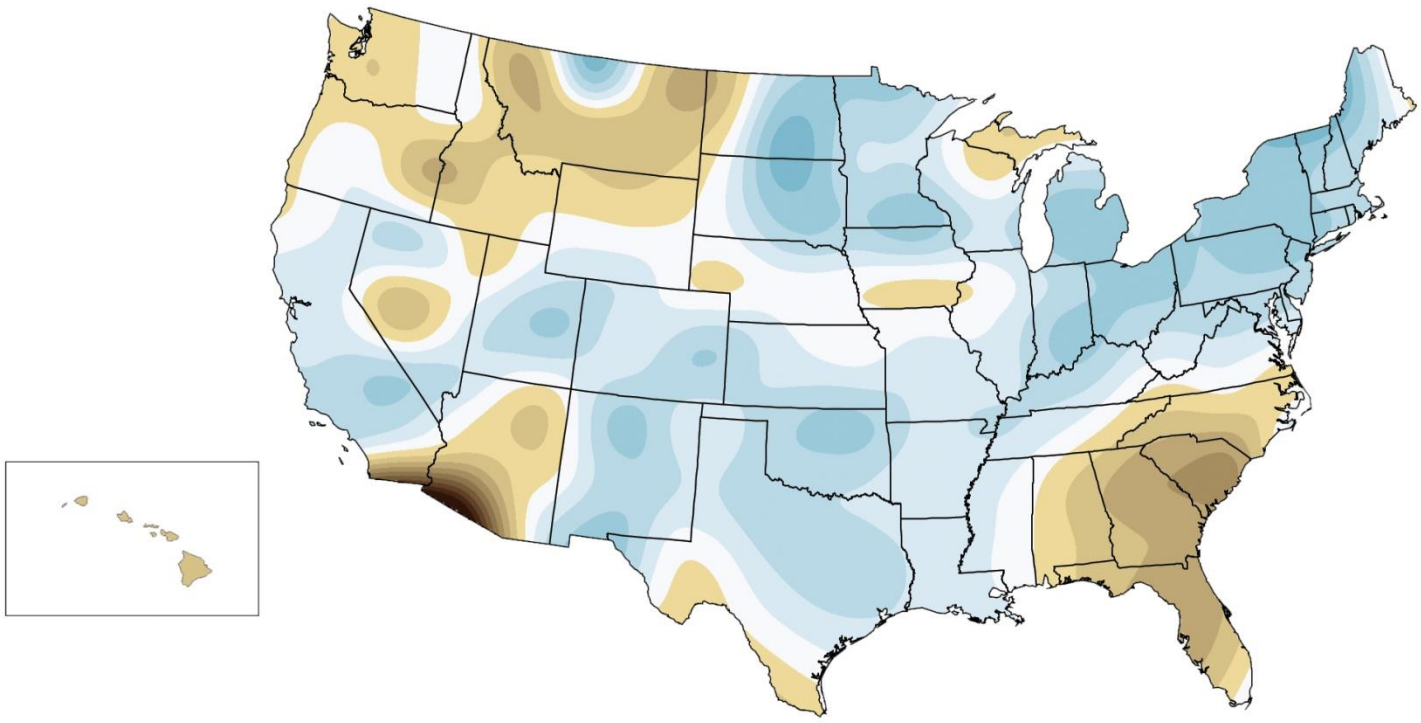

Inversion
Condensation

Lifting Condensation Level



Henry F. Diaz, Thomas W. Giambelluca, Jon K. Eischeid, 2011, Changes in the vertical profiles of mean temperature and humidity in the Hawaiian Islands, Global and Planetary Change, doi:10.1016/j.gloplacha.2011.02.007

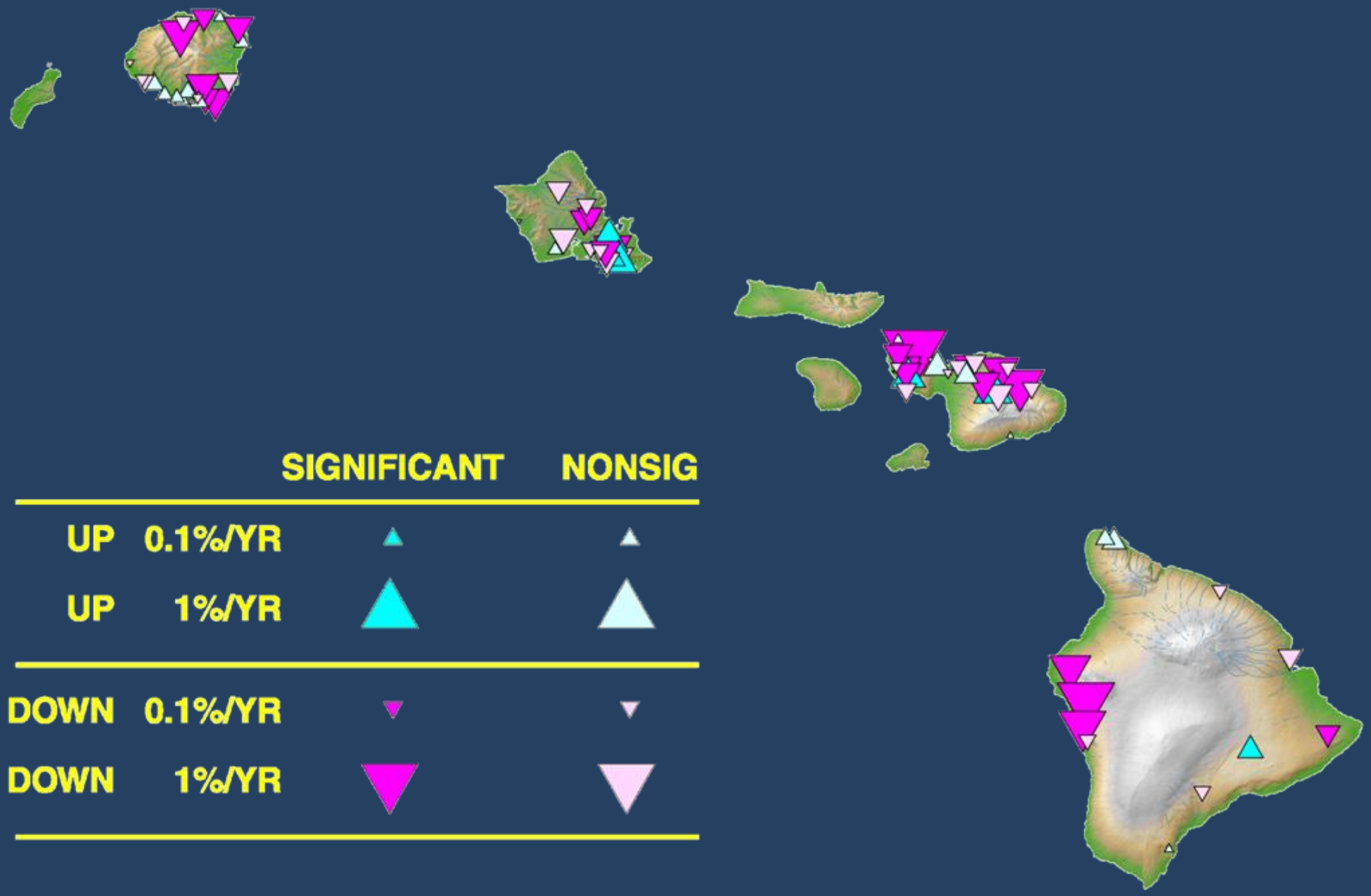
Rainfall (-15%)



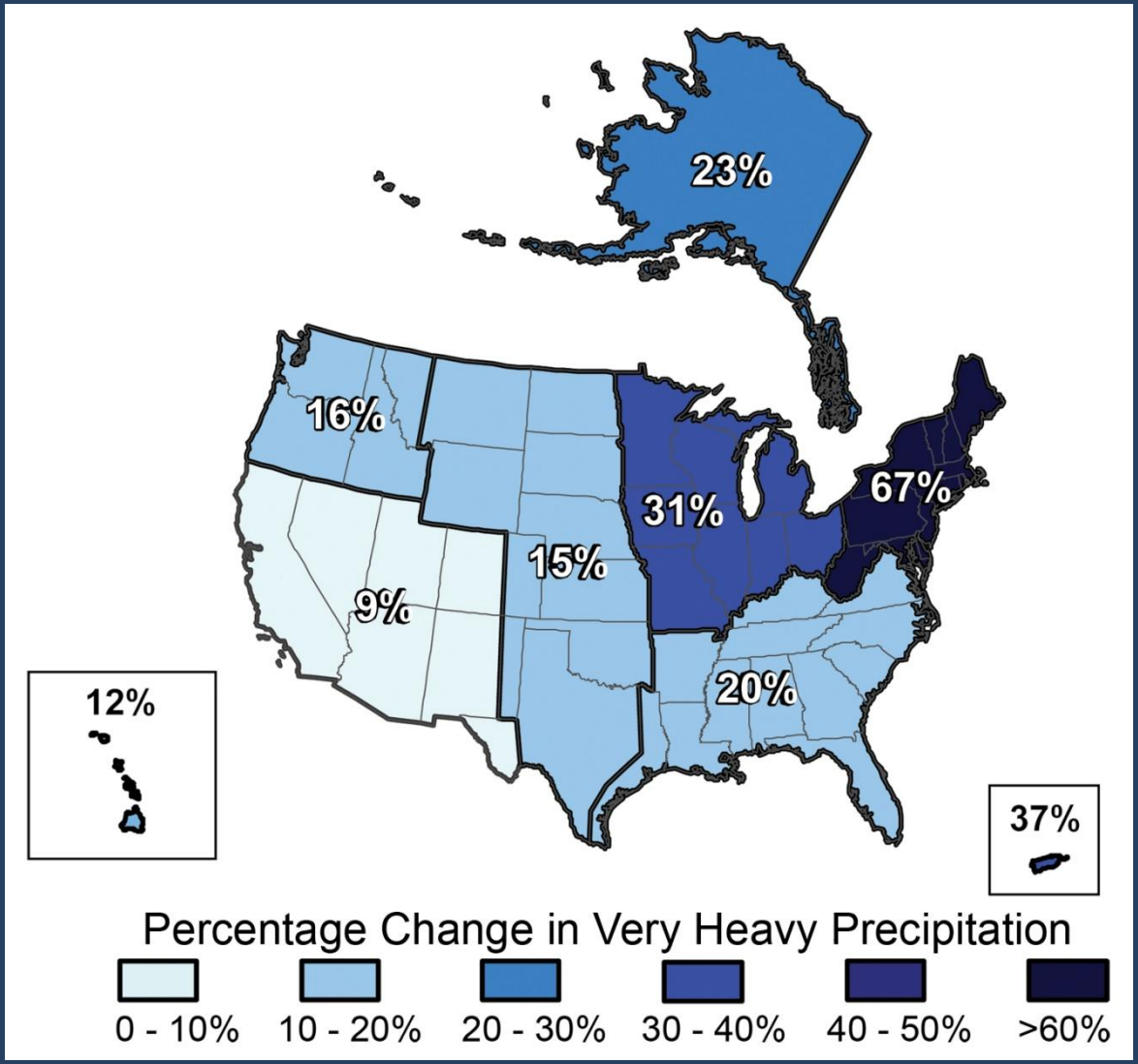
While U.S. annual average precipitation has increased about 5 percent over the past 50 years, there have been important regional differences as shown above.

P. Ya. Groisman, R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, J.H. Lawrimore, 2004 "Contemporary changes of the hydrological cycle over the contiguous United States, trends derived from *in situ* observations" *Journal of Hydrometeorology* 5(1): 64-85.

1913–2008 ANNUAL RAINFALL



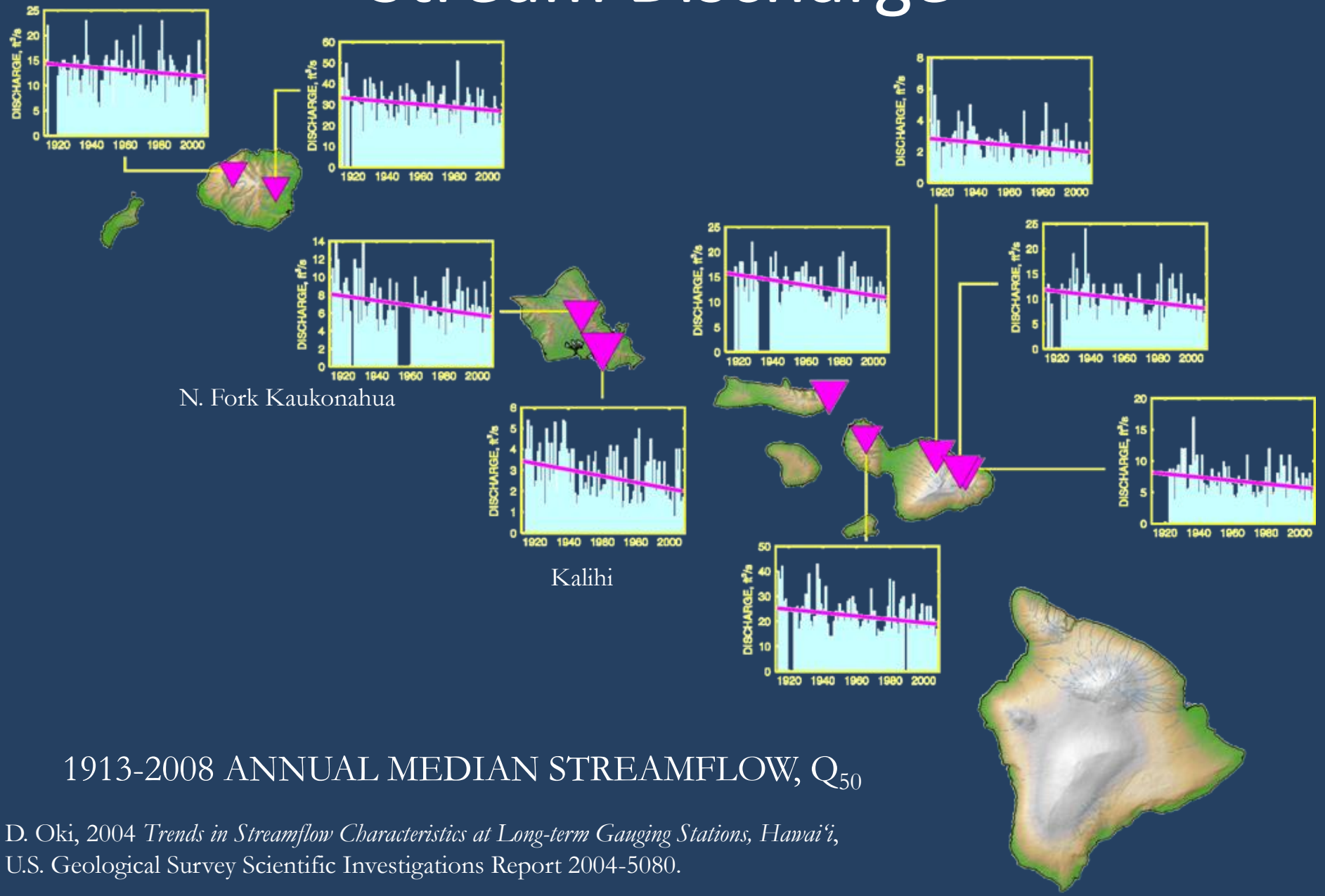
Rain Intensity (+12%)



Percentage increase in very heavy precipitation (heaviest 1% of all events) 1958-2007

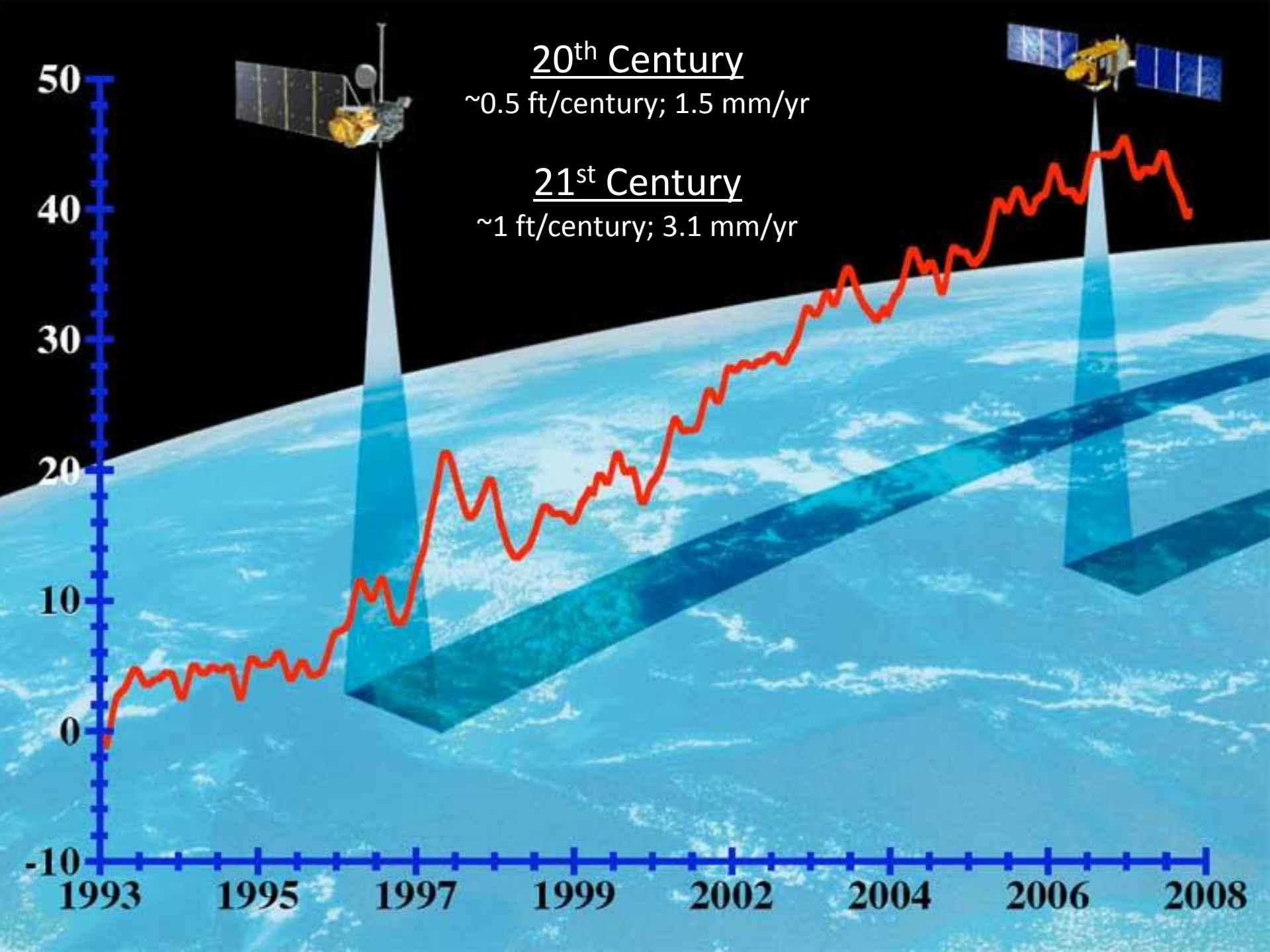
P. Ya. Groisman, R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, J.H. Lawrimore, 2004 "Contemporary changes of the hydrological cycle over the contiguous United States, trends derived from *in situ* observations" *Journal of Hydrometeorology* 5(1): 64-85.

Stream Discharge



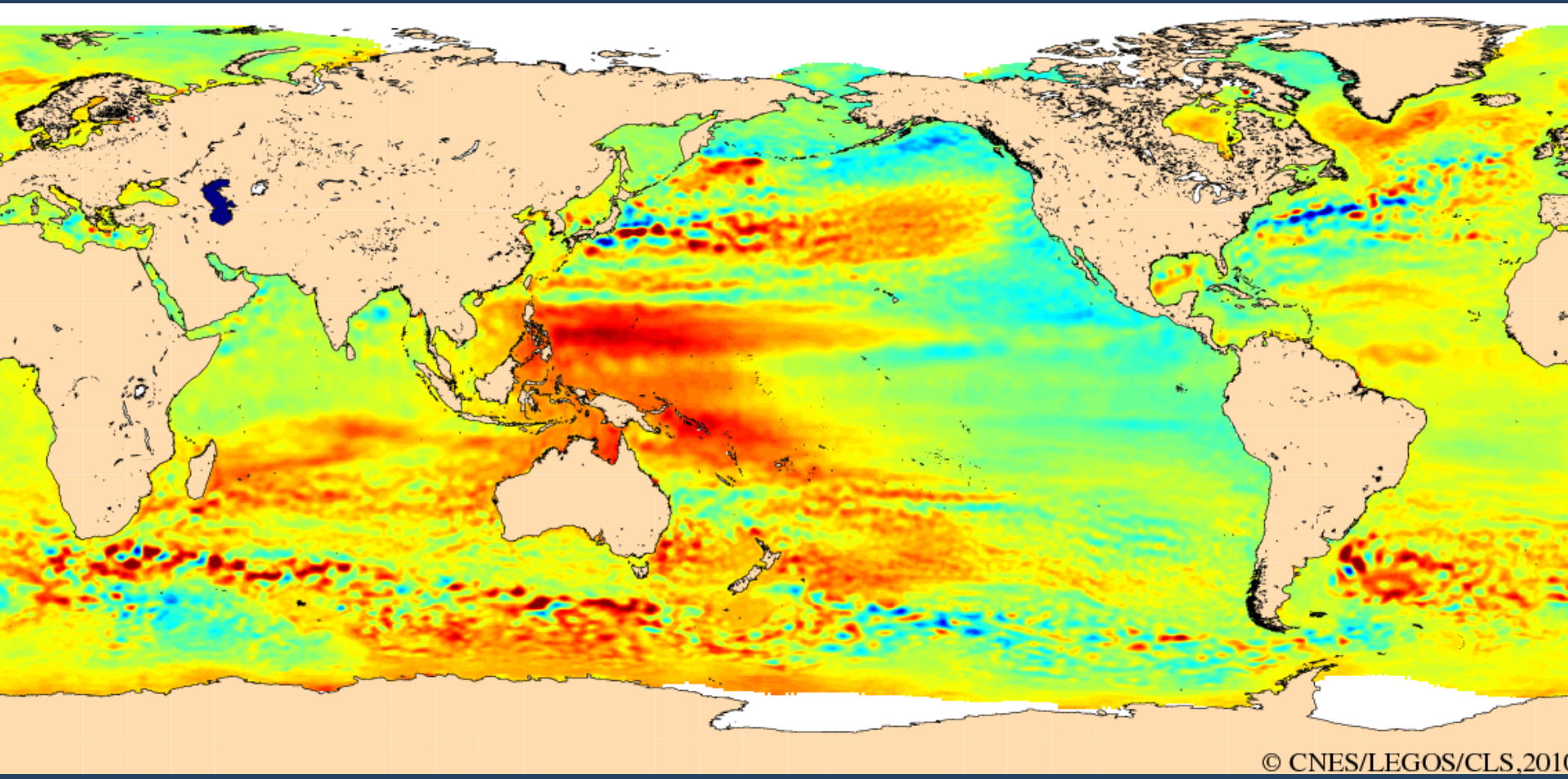
1913-2008 ANNUAL MEDIAN STREAMFLOW, Q_{50}

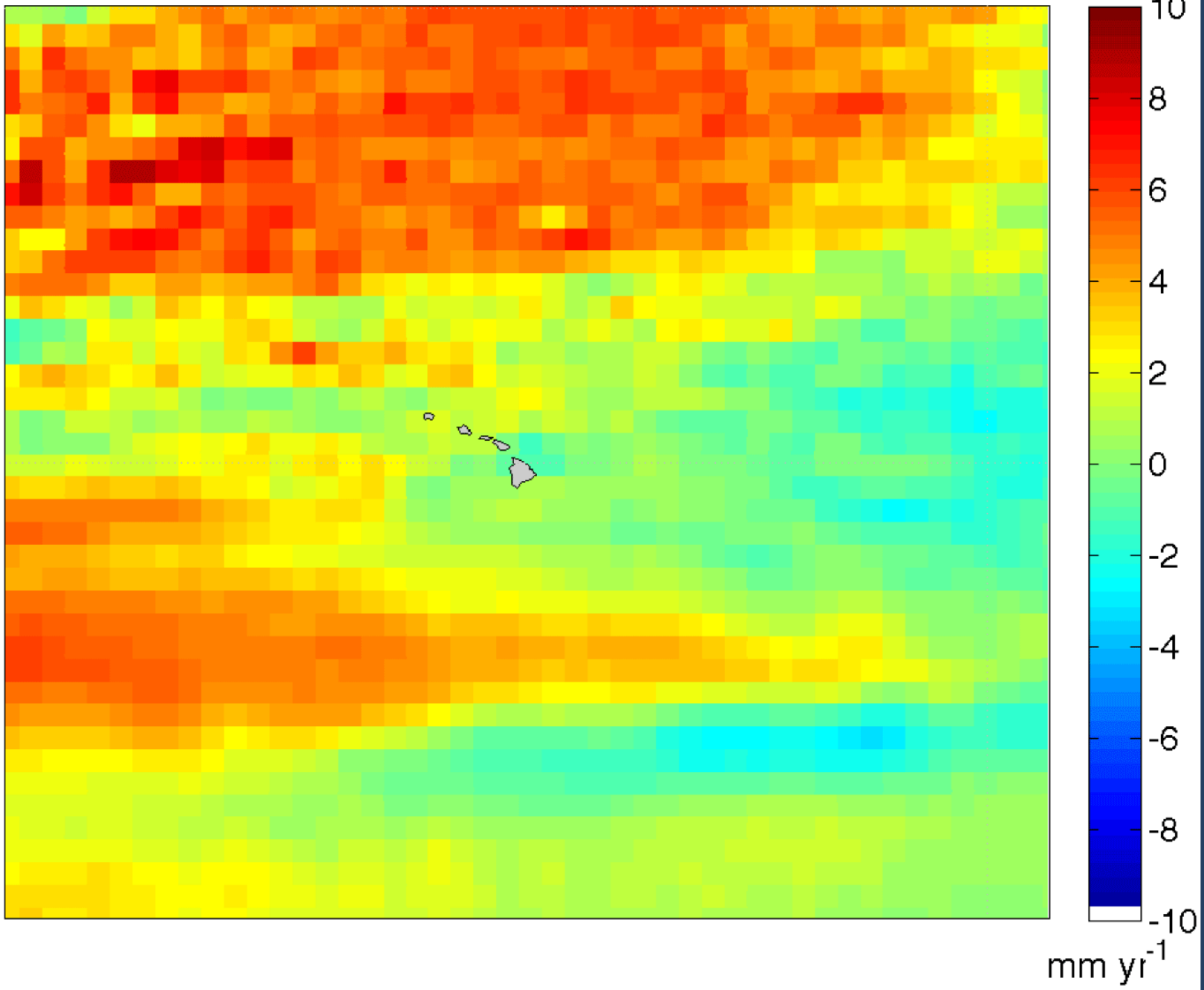
D. Oki, 2004 *Trends in Streamflow Characteristics at Long-term Gauging Stations, Hawai'i*, U.S. Geological Survey Scientific Investigations Report 2004-5080.


20th Century
~0.5 ft/century; 1.5 mm/yr
21st Century
~1 ft/century; 3.1 mm/yr
50
40
30
20
10
0
-10
1993
1995
1997
1999
2002
2004
2006
2008

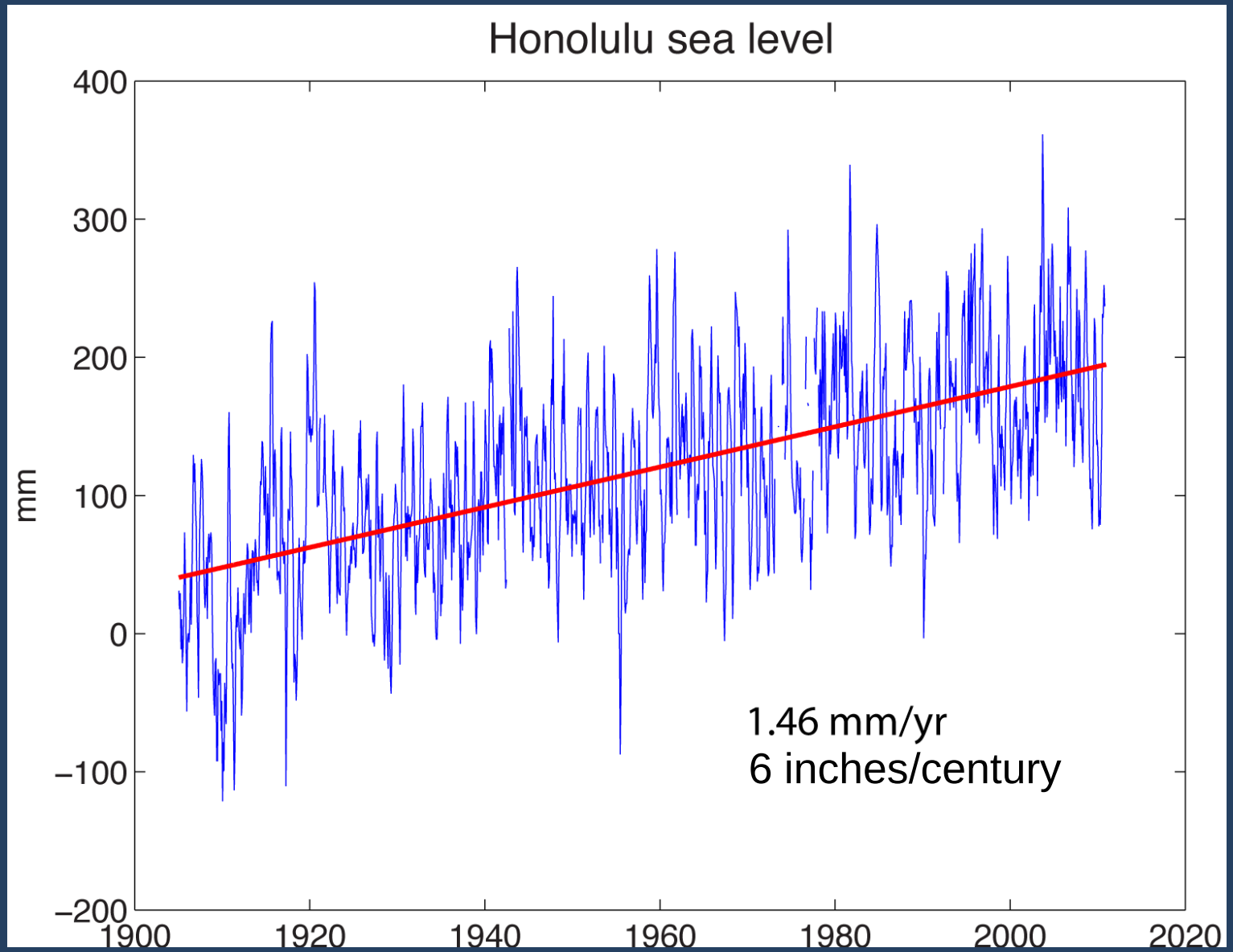

Sea level rise will be a
significant problem
NA HOKU II

Satellite Altimetry – 3.1mm/yr




10
8
6
4
2
0
-2
-4
-6
-8
-10
mm yr-1

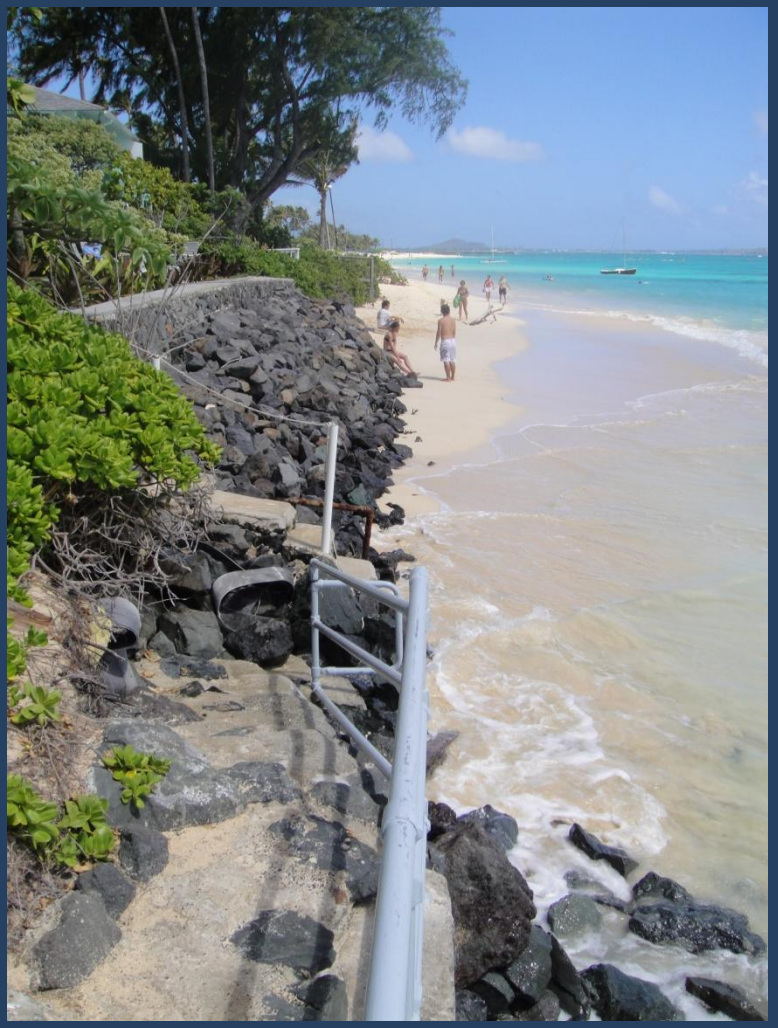
Sea Level


Honolulu sea level
400
300
200
100
0
−100
−200
mm
1900
1920
1940
1960
1980
2000
2020
1.46 mm/yr
6 inches/century

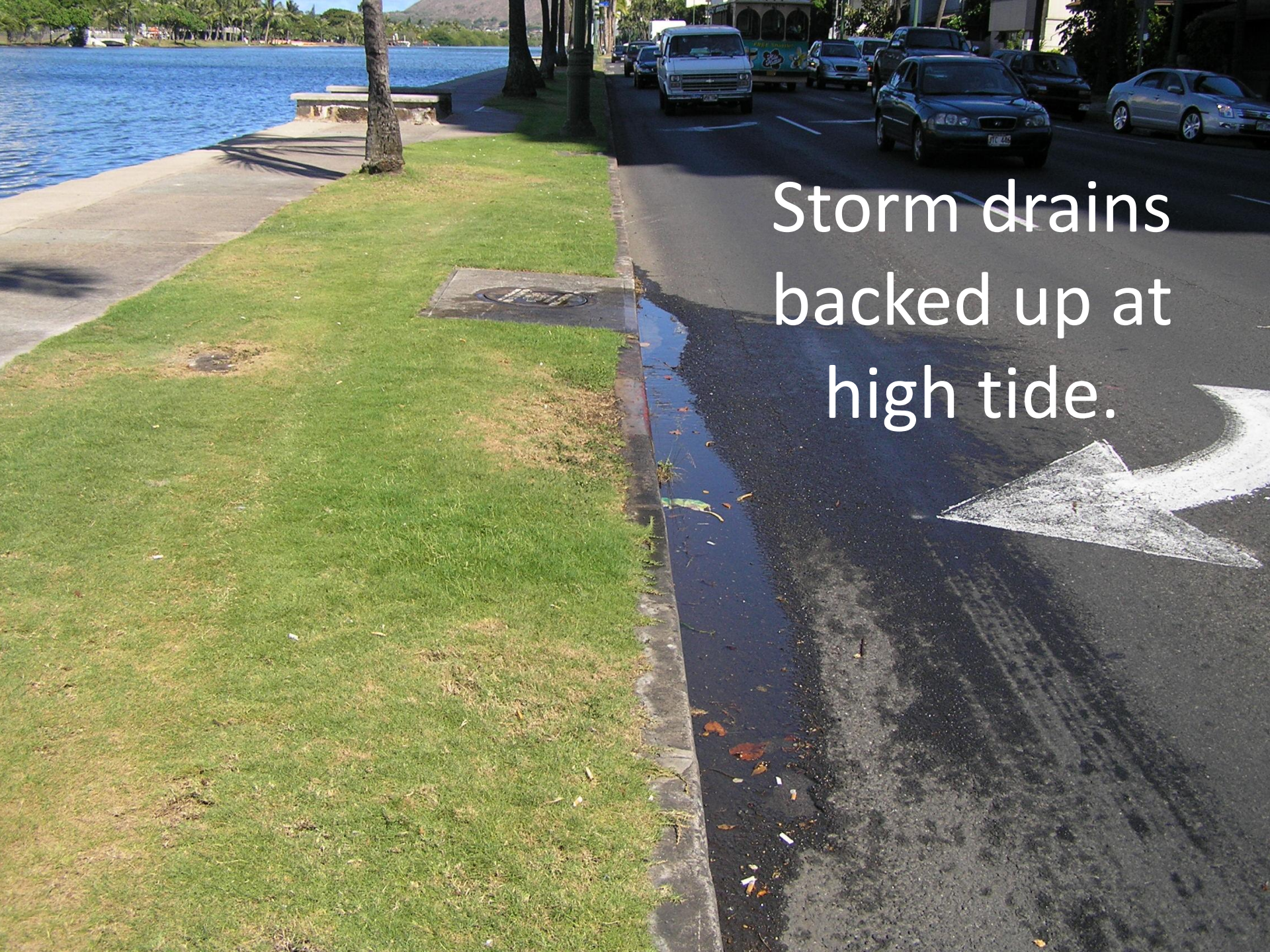
Erosion is the dominant trend on Hawaii beaches

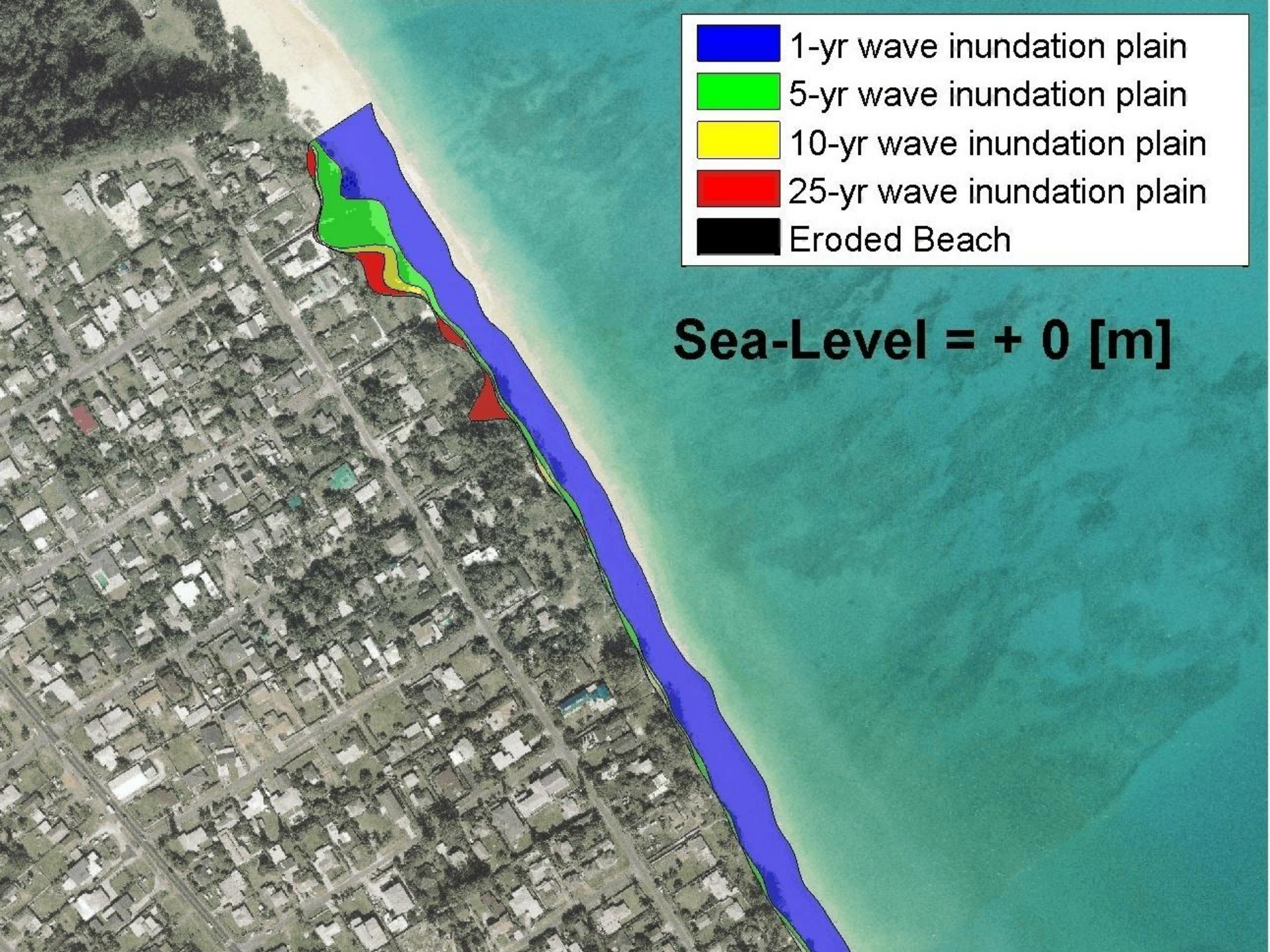
Hawaii, overall (Kauai, Oahu, Maui)

- 70% of beaches eroding
- 13.6 miles (9%) of beaches completely lost to erosion
- Avg. rate = -0.4 ft/yr

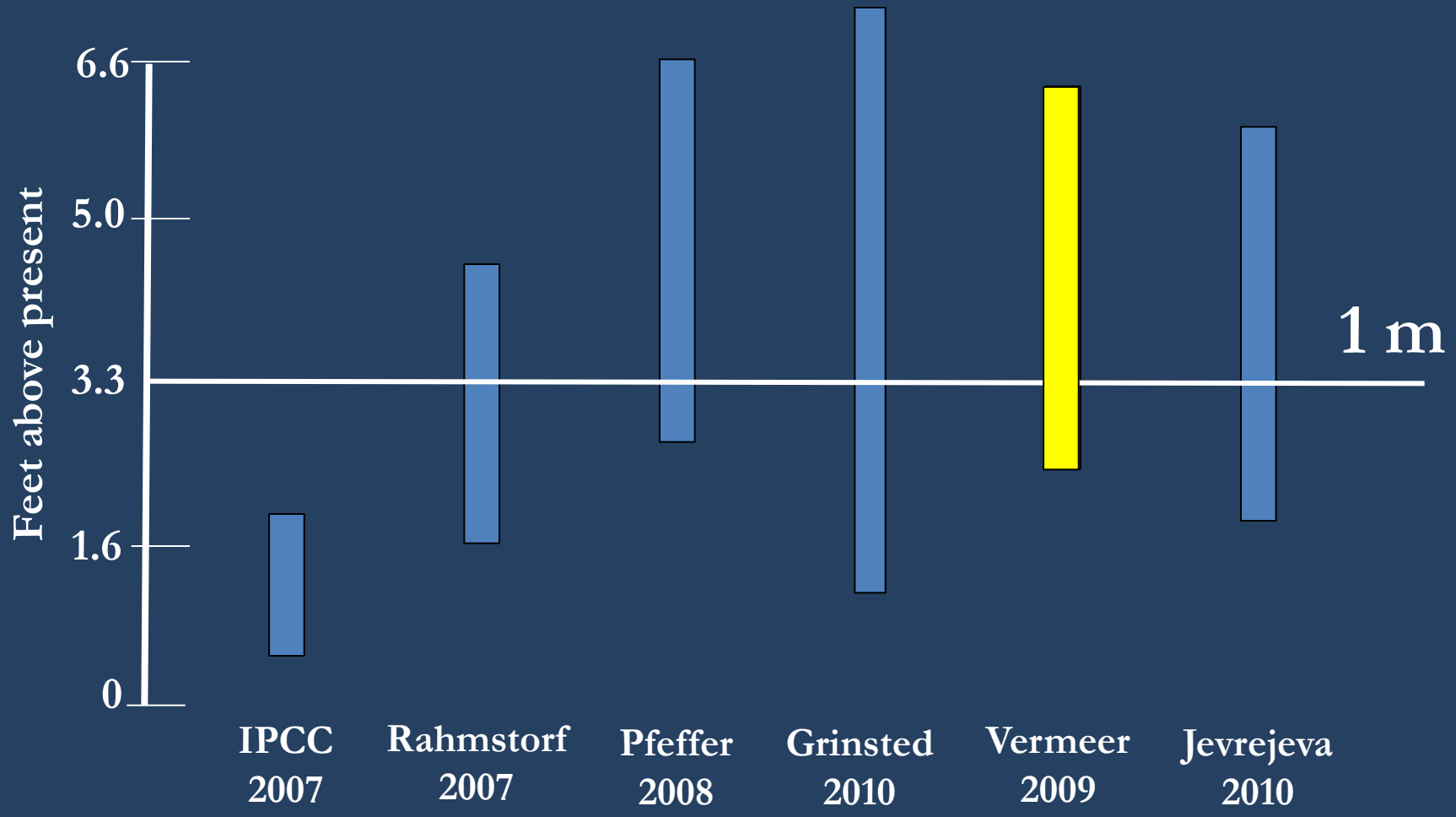


Source: Fletcher, *et al.*, (in press) National assessment of shoreline change: historical shoreline changes in the Hawaiian islands. USGS open-file report.


Storm drains
backed up at
high tide.

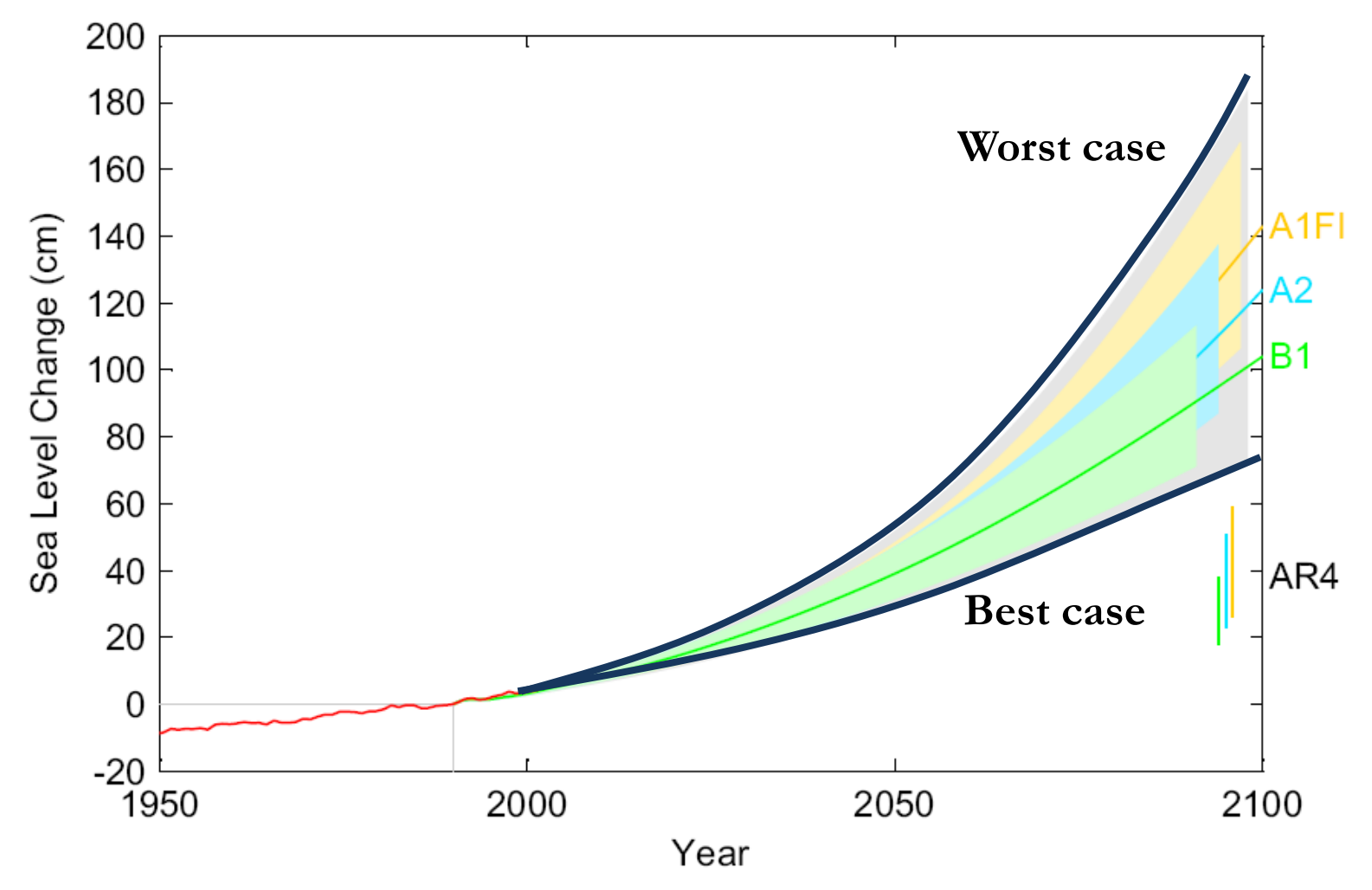

1-yr wave inundation plain
5-yr wave inundation plain
10-yr wave inundation plain
25-yr wave inundation plain
Eroded Beach
Sea-Level = + 0 [m]

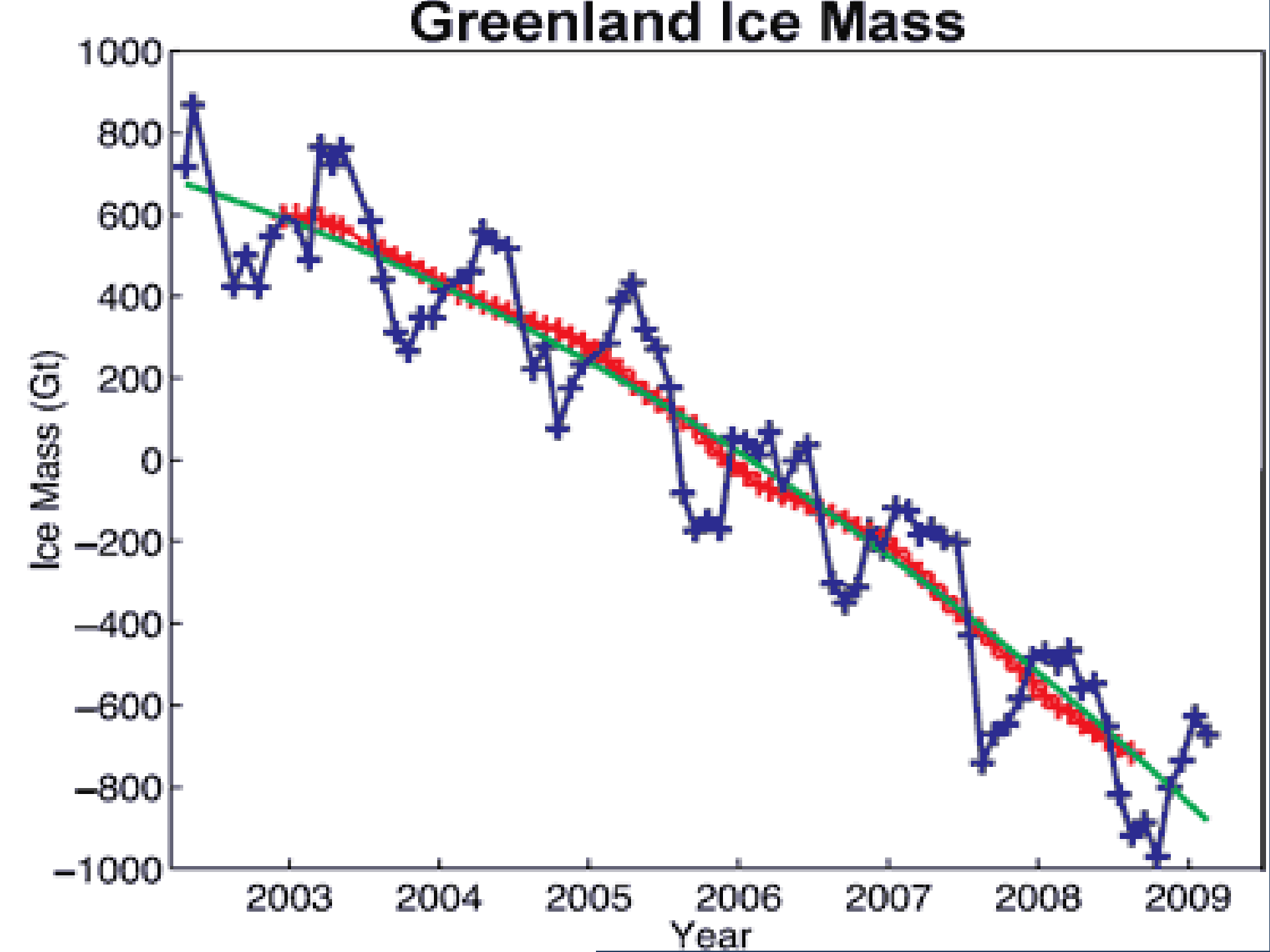
Sea level Estimates – 2100
2.5 to 6.2 ft

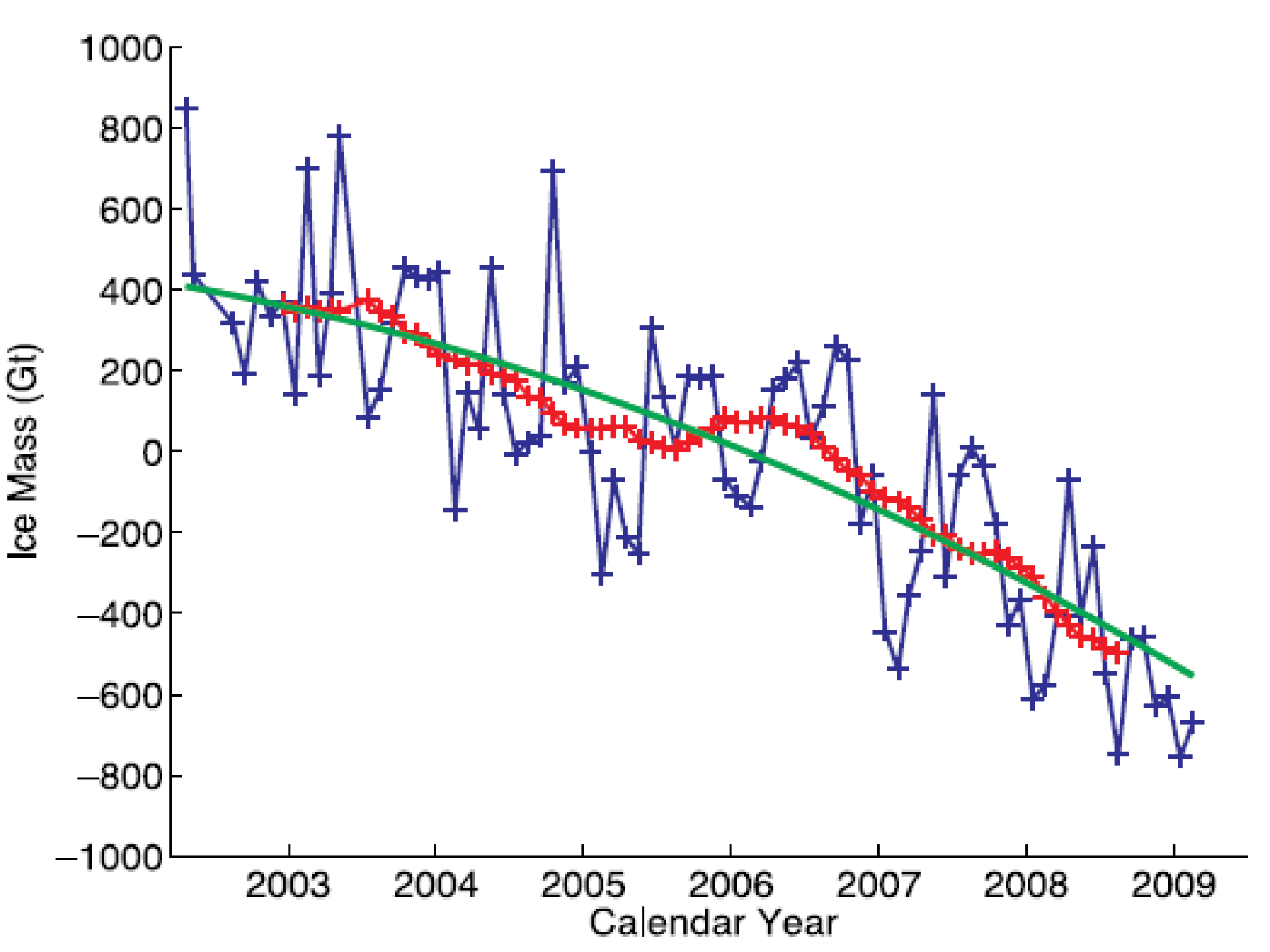


Projected Sea Level

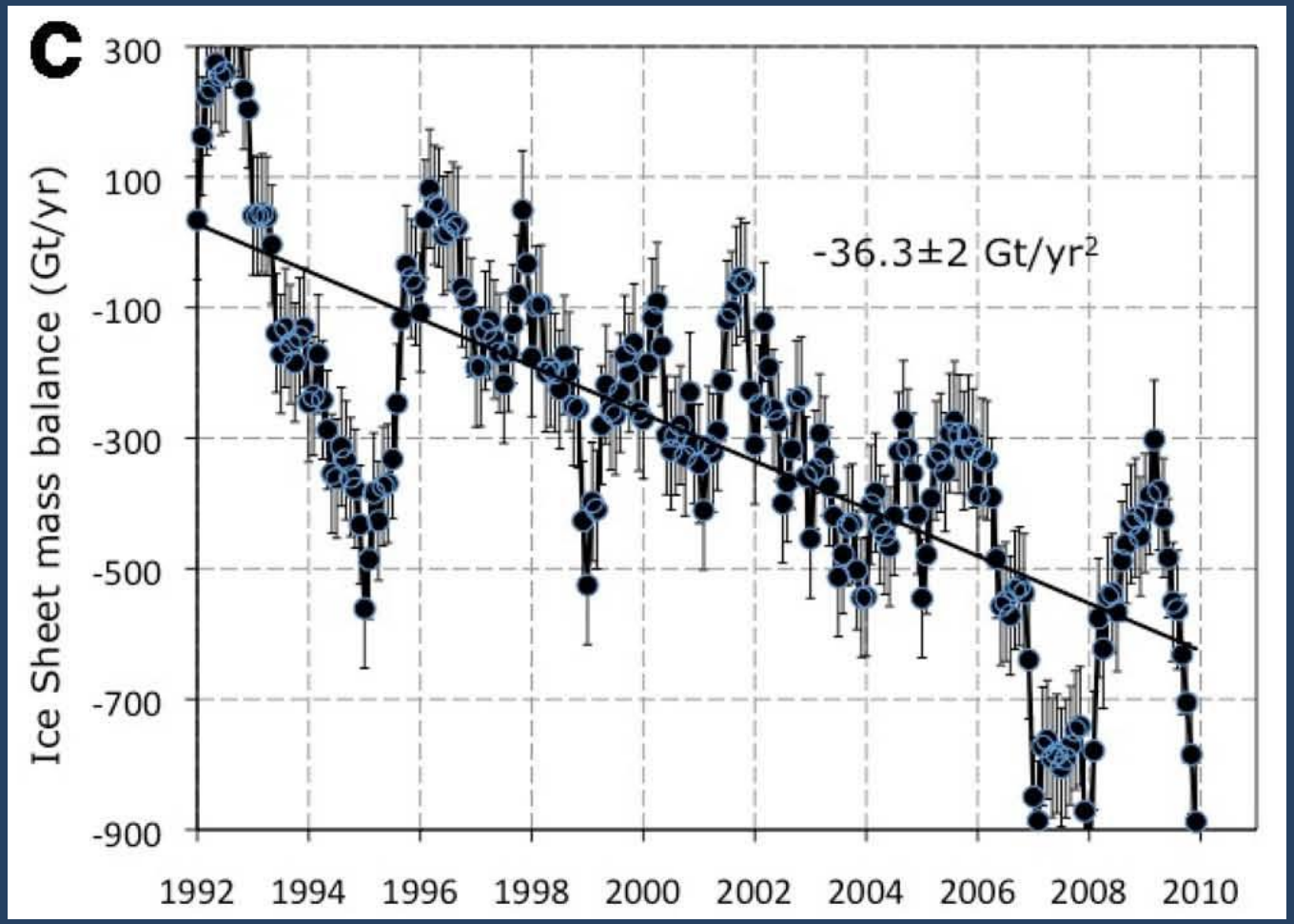
2.5-6.2 ft Vermeer and Rahmstorf, 2009




Greenland Ice Mass
1000
800
600
400
200
0
−200
−400
−600
−800
−1000
Ice Mass (Gt)
2003
2004
2005
2006
2007
2008
2009
Year


1000
800
600
400
200
0
−200
−400
−600
−800
−1000
Ice Mass (Gt)
2003
2004
2005
2006
2007
2008
2009
Calendar Year

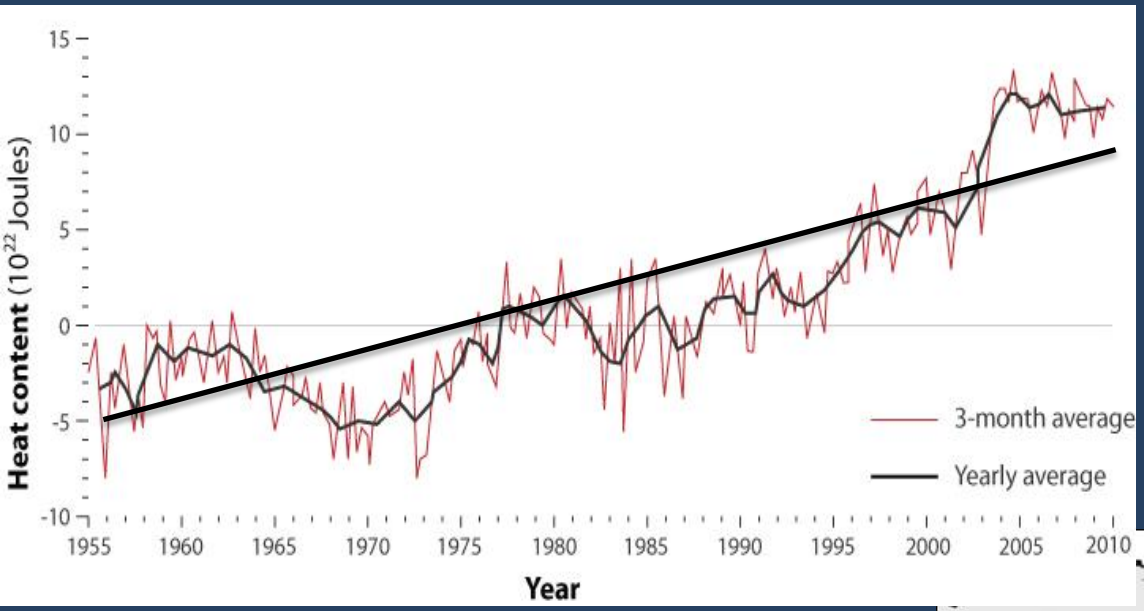
Combined Greenland + Antarctica melting = 9 inches sea level rise by 2050

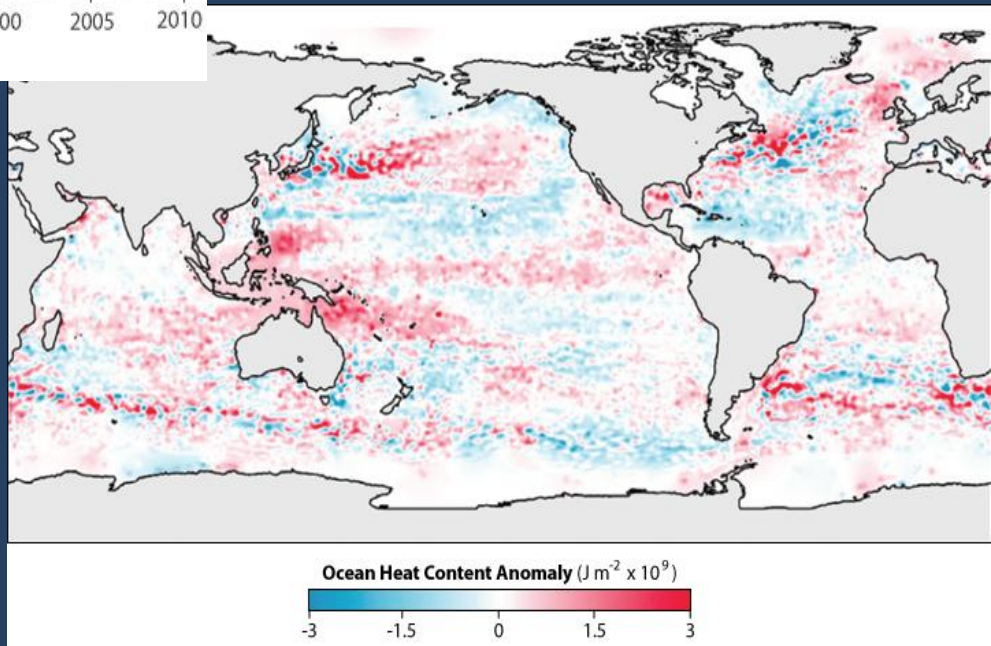


Rignot, E., I. Velicogna, M. van den Broeke, A. Monaghan, and J. Lenaerts (2011), Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophys. Res. Lett., doi:10.1029/2011GL046583, in press.

Thermal expansion of shallow ocean

3.5 inches sea level rise by 2050





Cazenave, A., Llovel, W., 2010, Contemporary sea level rise, Ann. Rev. Mar. Sci., 2:145-73

How high?

Total rise of
1 ft by 2050
2.5 to 6.2 ft by 2100

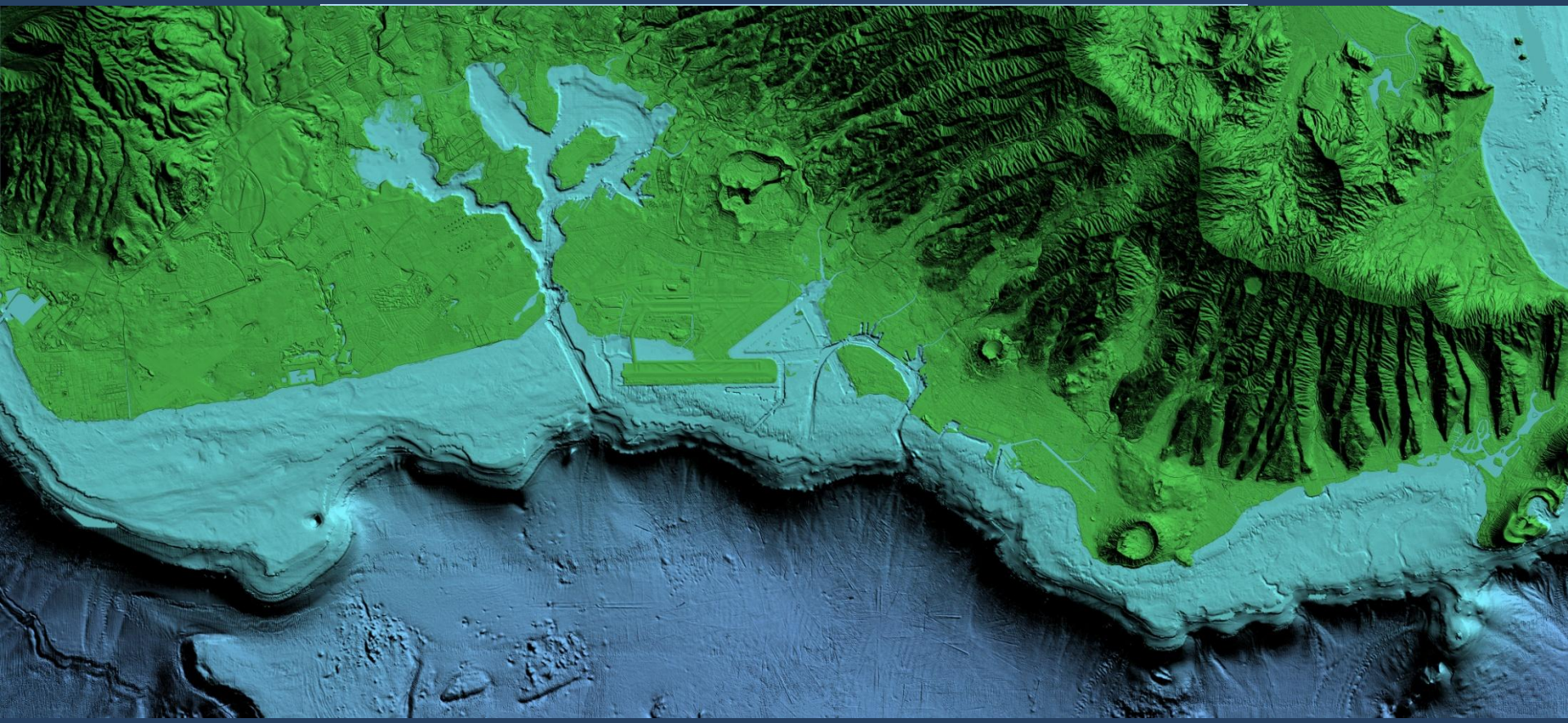
7.6 mm/yr

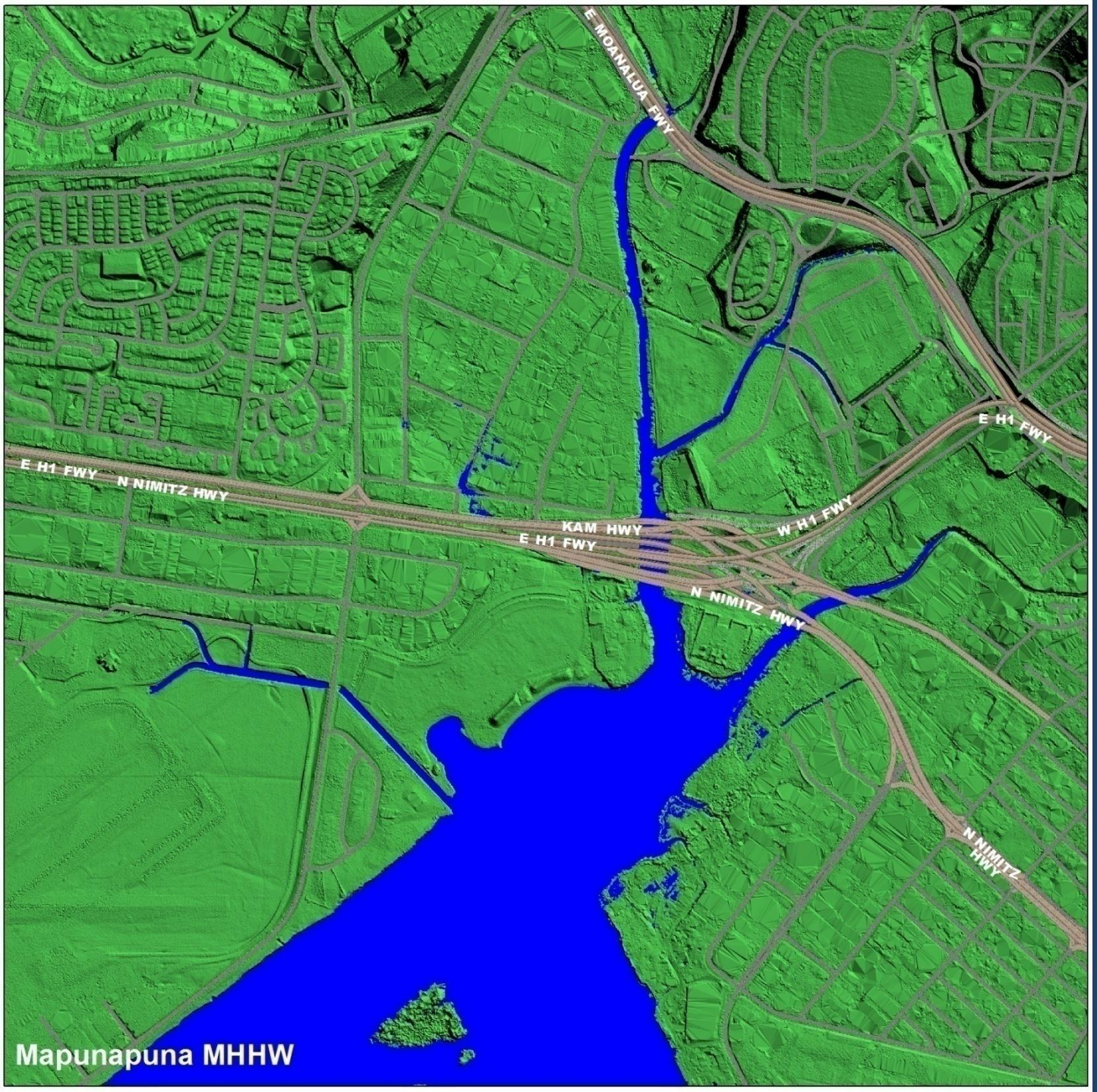
Does not count deep ocean warming or alpine glaciers.

Hawaii has thus far lagged behind global trends and may continue to.

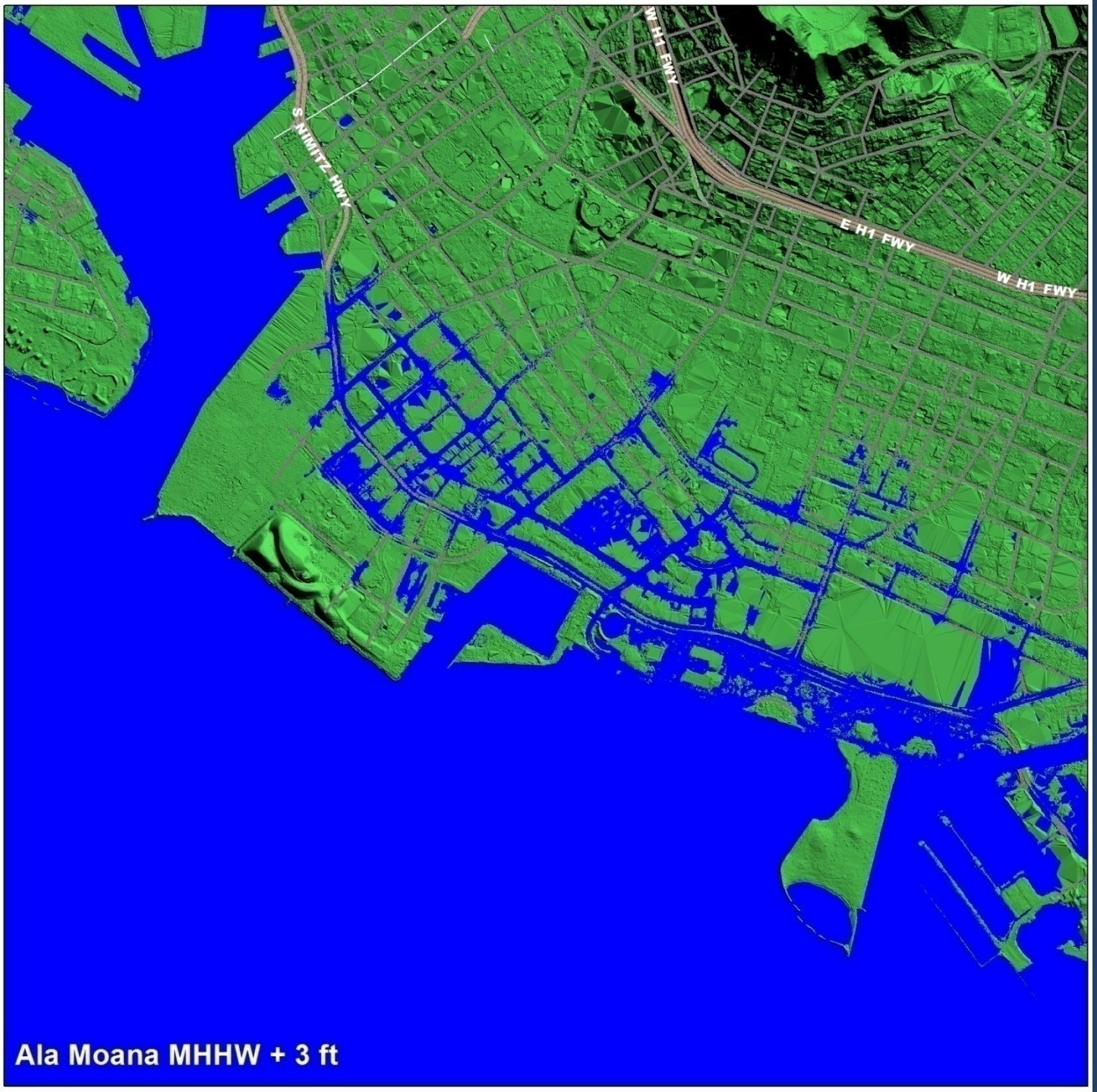
What assets are vulnerable to 1 ft of sea level rise?

Rignot, E., I. Velicogna, M. van den Broeke, A. Monaghan, and J. Lenaerts (2011), Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophys. Res. Lett., doi:10.1029/2011GL046583, in press.

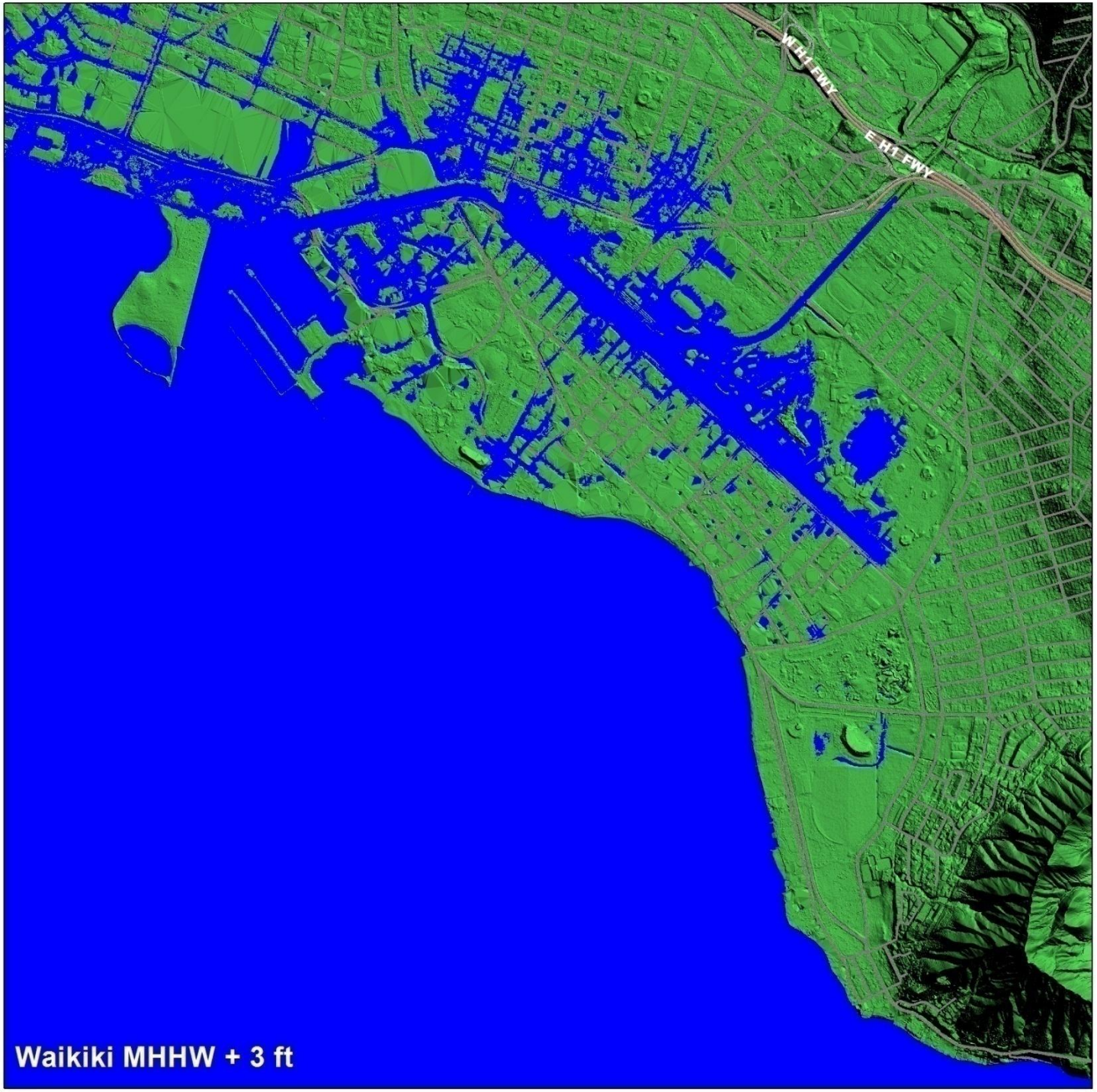


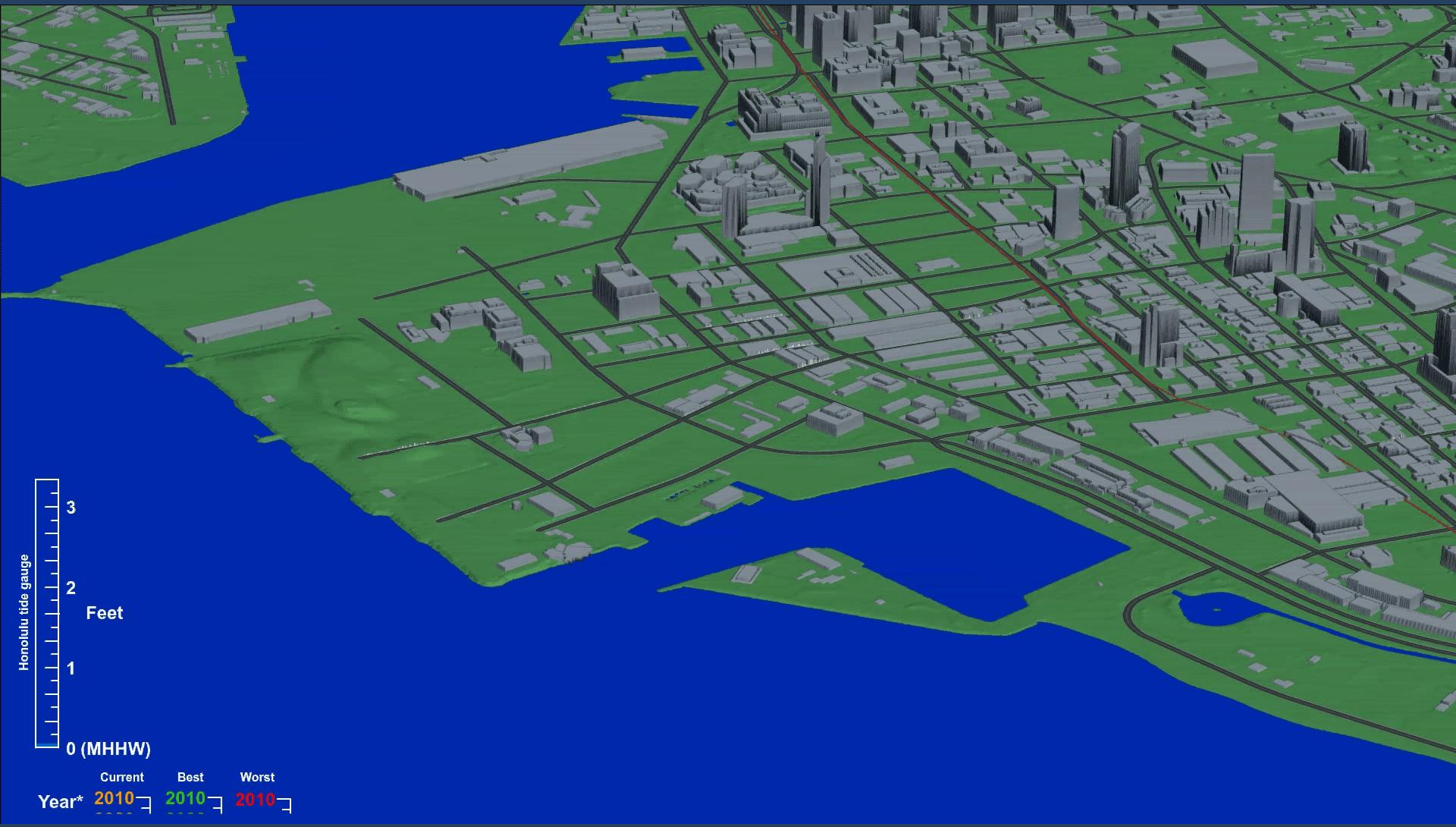

E MOANALUA FWY
E H1 FWY
E H1 FWY
N NIMITZ HWY
KAM HWY
E H1 FWY
W H1 FWY
N NIMITZ HWY
N NIMITZ HWY
Mapunapuna MHHW


W MOANALUA FWY
KAM HWY
E H1 FWY
E H1 FWY
W MOANALUA FWY
KAM HWY
E H1 FWY
N NIMITZ HWY
KAM HWY
Airport Area MHHW + 3 ft


S NIMITZ HWY
W H1 FWY
E H1 FWY
W H1 FWY
Ala Moana MHHW + 3 ft


E H1 FWY
N NIMITZ HWY
W H1 FWY
E H1 FWY
PALI HWY
N NIMITZ HWY
S NIMITZ HWY
E H1 FWY
Downtown MHHW + 3 ft


W H-1 FWY
E H-1 FWY
Waikiki MHHW + 3 ft


Homolulu tide gauge
3
2
Feet
1
0 (MHHW)
Current
Best
Worst
Year*
2010
2010
2010

Adapting to sea-level rise and inundation

1. Explore the issues of sea level rise with the community to develop a shared vision of what is at risk and the qualities stakeholders want to protect (community-based climate risk management).
2. Map the problem using best and worst case scenarios.
3. Develop adaptation strategies
   a) Building codes
   b) Retreat strategies
   c) Defense strategies
   d) Food, flood, transportation engineering
4. No regrets policy – areas troubled now, are likely to get worse
5. Identify funding, create plans, establish an authority
6. Stage activities, apply triage priorities

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

USGS science for a changing world


Thank you

Missing Data

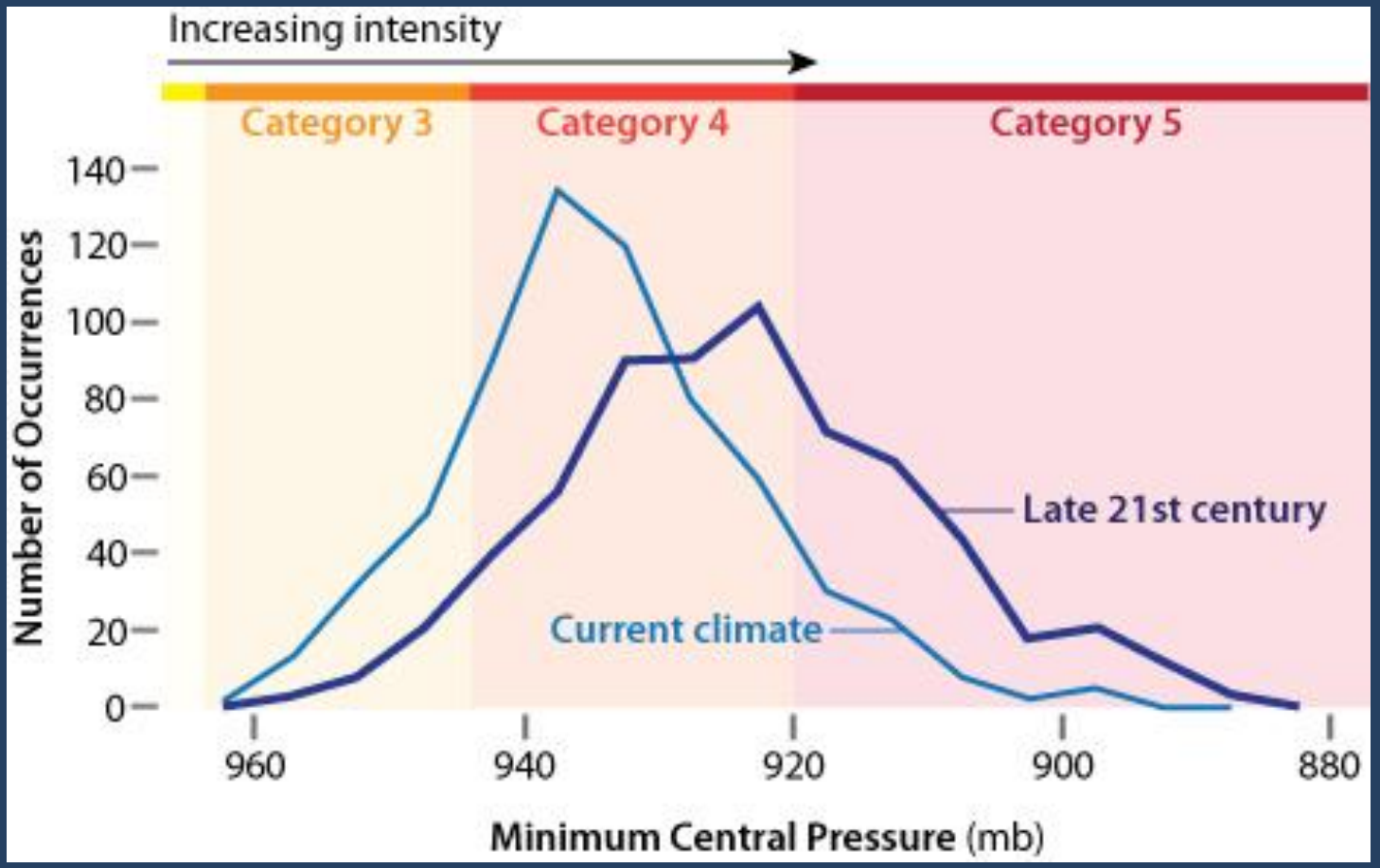
- Water Table Height maps and how the water table behaves
- Current Problem Area maps
  - Flooding
  - Wave overwash
  - Erosion
- Commuter bottlenecks
- Analysis bringing these together and strategy to address

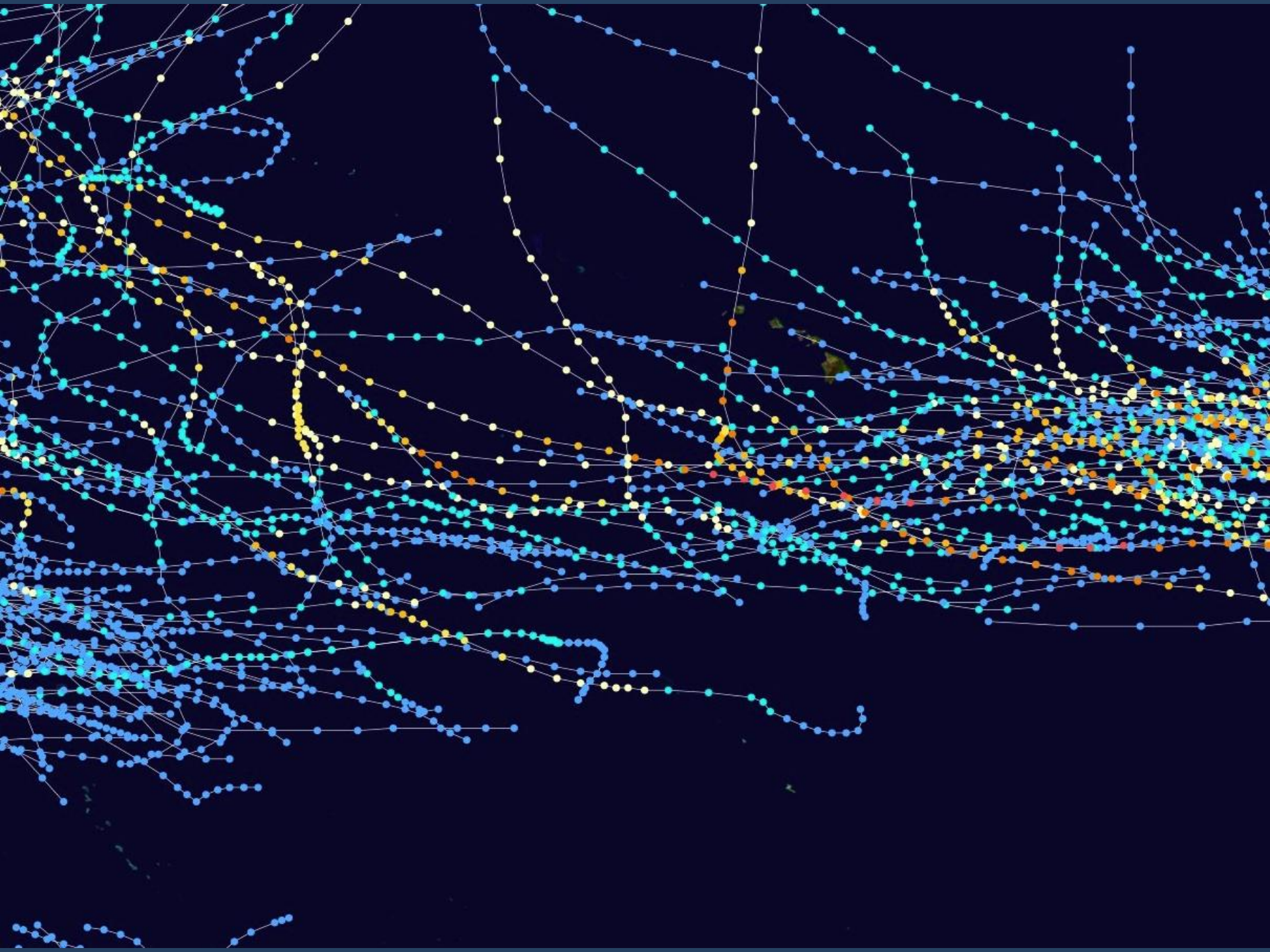
Impacts? (+1m)

- Rising water table, increasing rain intensity, no drainage = FLOODING
- Wave overtopping = CLOSED ROADS
- Vulnerable infrastructure and environments = ANYTHING <2M ELEVATION
- High traffic flow/Low elevation
  - Hawai΄i Kai, Waikiki, Kalihi, Airport Industrial
  - N. Nimitz, Dillingham, Ala Moana, Kapiolani
  - Kamehameha (windward and N. Shore)
  - Kalaniana'ole
- Tsunami, storm surge, seasonal swell = RISING VULNERABILITY

Storms in a warmer world

- Fewer hurricanes but stronger





Hawaii's future is on trend to be

- Warmer
- Drier
- Susceptible to severe storms
- Susceptible to flooding
- Susceptible to accelerated coastal erosion
- Depleted fisheries and
- Stressed coral reef ecosystems.

ecologic consequences that may further affect things like water supply (think of ecohydrologic feedbacks), opportunities for fire and invasive species, and perhaps increased coastal sedimentation.

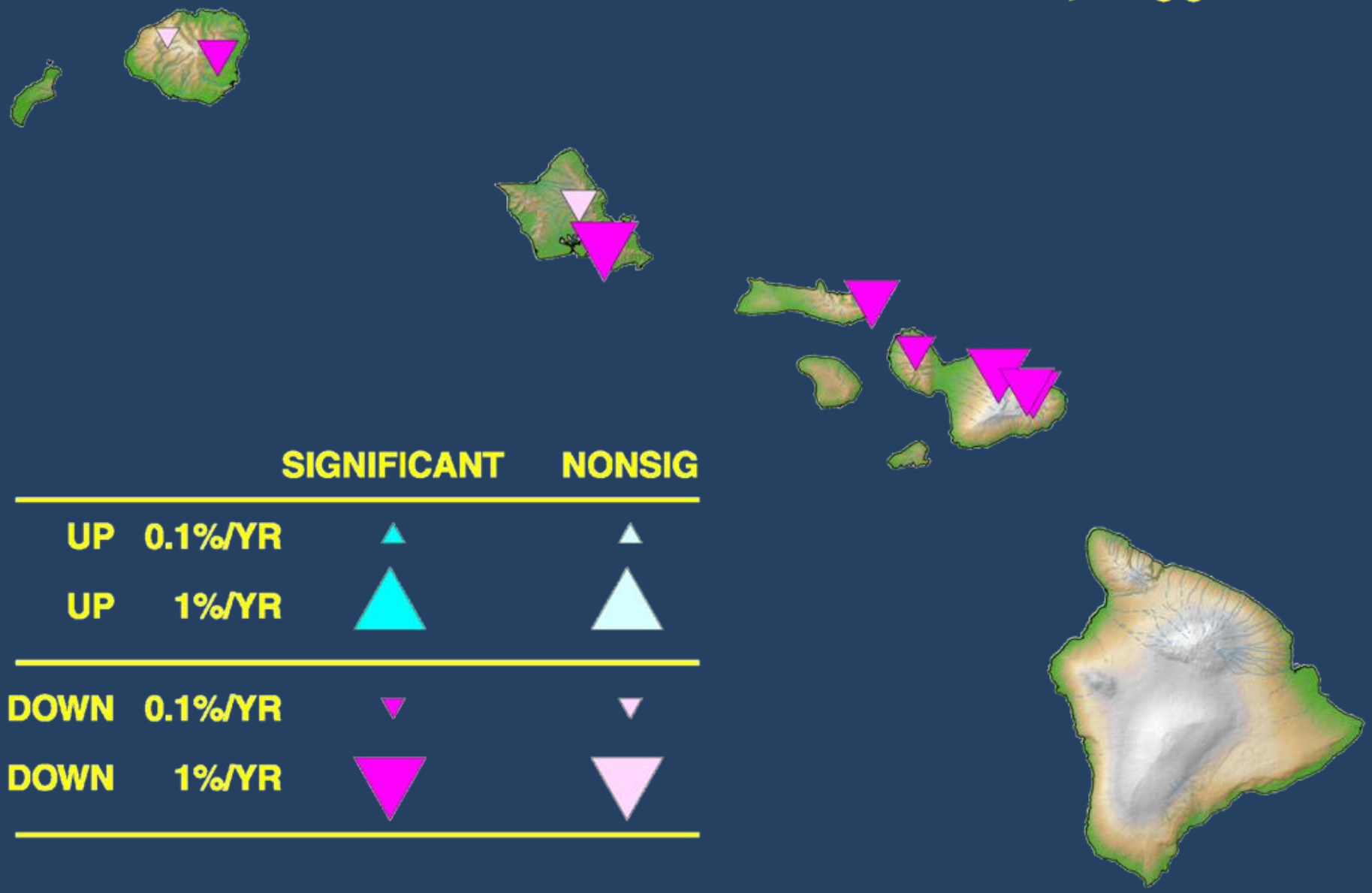
I think the message should also be that the effects/damage/costs don't occur at once, like a tsunami, but decisions made now, can influence ultimate strategies.

Some of the reactions we've heard include:

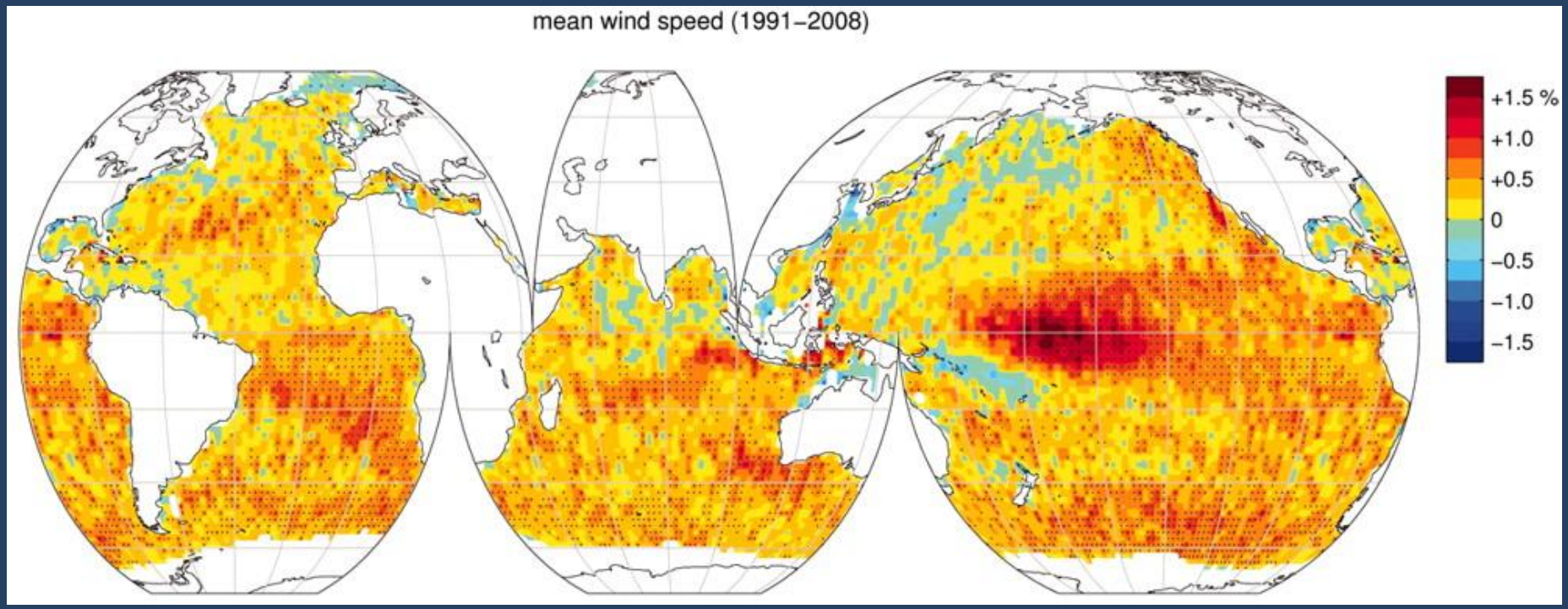
- Science and technology will come up with solutions in time, so we don't have to do anything now
- The effects are so huge and insurmountable that nothing can be done to deal with it
- Discussion can be postponed to much later

- variable setback lines in some areas;
- new rules in Special Management Area permit review to incorporate sea level rise impacts as part of the review process;
- sea level rise impact assessment in any major infrastructure investments or repairs within an area subject to at least periodic flooding by 2050;
- updating building standards in expanded flood prone areas.

1913–2008 STREAMFLOW, Q_{90}

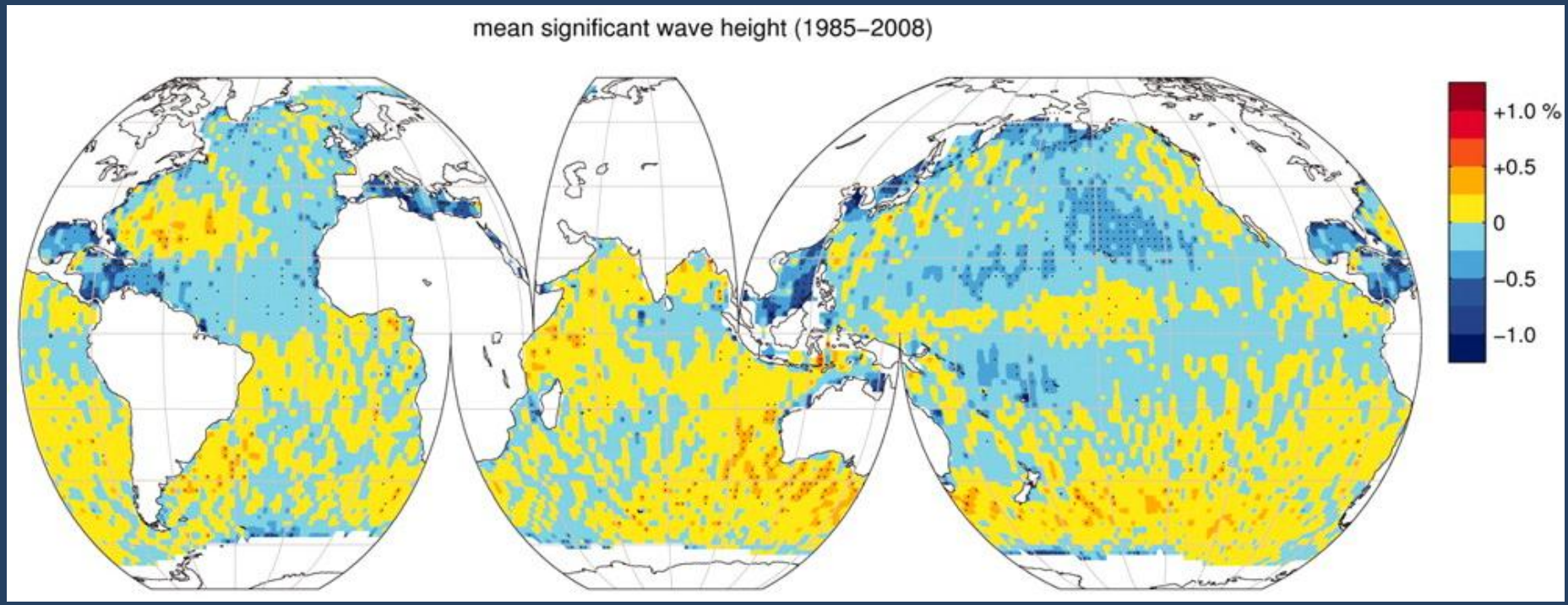


Global trend of increasing wind speed; the rate of increase is greater for extreme events compared to the mean condition.



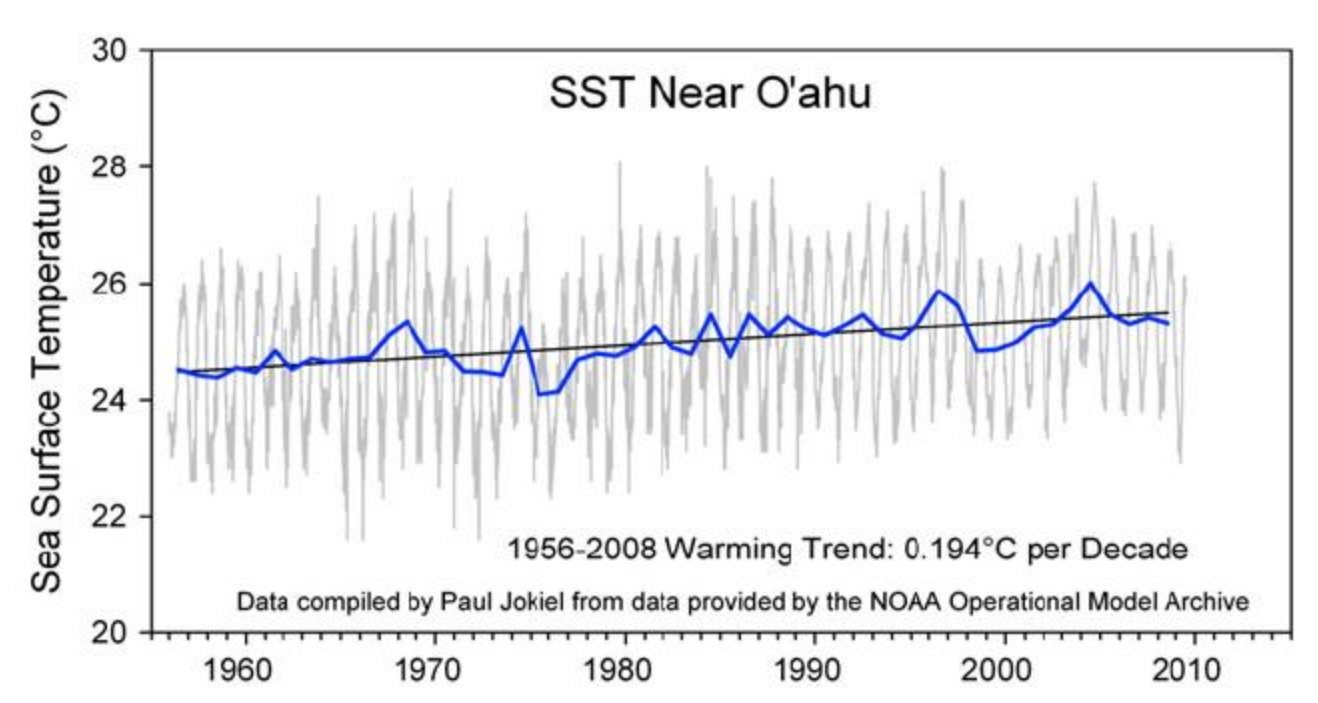
The only significant exception to this positive trend is the central north Pacific, where there are smaller localized increases in wind speed of approximately 0.25% per year and some areas where there is a weak negative trend.

The mean wave height trend shows a relatively neutral condition



Large regions of the north Pacific and north Atlantic show a weak negative trend (0.25% per year), as does much of the equatorial regions of all oceanic basins.

Sea Surface Temperature



Jokiel, P.J., Brown, E.K., 2004. Global warming, regional trends and inshore environmental conditions influence coral bleaching in Hawaii. Global Change Biol. 10, p. 1627–1641.